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Issued June 10, 1907.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 187.

A. C. TRUE, Director.

STUDIES

ON

THE DIGESTIBILITY AND NUTRITIVE VALUE OF LEGUMES

AT THE

UNIVERSITY OF TENNESSEE,

1901-1905.

BY

CHAS. E. WAIT, PH. D., F. C. S.,

Professor of Chemistry, University of Tennessee.



WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1907.

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A. C. TRUE, Director.

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LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., March 24, 1907.

SIR: I have the honor to transmit herewith a report of investigations conducted in 1901-1905 by Charles E. Wait, Ph. D., F. C. S., professor of chemistry at the University of Tennessee, as a part of the nutrition investigations carried on under the auspices of this Office.

In the course of investigations Professor Wait has had the cooperation and assistance of Prof. C. O. Hill and Messrs. C. A. Mooers, W. K. Hunter, C. G. Schenk, T. M. Powell, and W. H. Brown, all of the University of Tennessee.

The present bulletin reports 72 experiments, made for the purpose of studying the digestibility of red kidney beans, white navy beans, and three varieties of cowpeas, namely, whippoorwill peas, clay peas, and lady peas. The results obtained with cowpeas are particularly interesting, as they show that this typical southern legume has very much the same nutritive value as the better known varieties of beans. When their distinctive and pleasant flavor is taken into account, as well as the many ways in which cowpeas may be prepared for the table, it seems obvious that their use as a food might be profitably extended.

Believing that the investigations reported furnish data of practical as well as scientific interest, it is recommended that the report be published as Bulletin 187 of this Office.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

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DIGESTIBILITY AND NUTRITIVE VALUE OF LEGUMES.

INTRODUCTION.

The family of plants commonly known as pulse or legumes have long been widely recognized as valuable sources of food. The lentil (*Lens esculenta*), for example, which is in common use in Asia and in Mediterranean countries and less extensively elsewhere, is among the oldest of food plants and perhaps one of the first ever cultivated. Another member, the soy bean (*Glycine hispida*), has for many centuries been used by the Chinese and Japanese in the manufacture of certain food preparations that are an indispensable part of their diet, giving flavor and relish and supplying in considerable measure the very essential ingredient—protein—that in the diet of western people is furnished largely by animal food. The Indians had some varieties of beans and peas under cultivation when this continent was discovered. Representatives of the legume family are used as food in all lands where the climate permits of their cultivation. Taking all countries together, they rank next to the cereals in importance among vegetable foods.

Different kinds of legumes are in common use in different parts of this country. In the northern and eastern sections the white or navy and red kidney beans (*Phaseolus vulgaris*) and the Lima bean (*Phaseolus lunatus*) are more commonly used. These are used also to some extent in the Southern States, but there the cowpea (*Vigna catjang*) is perhaps of more importance. In the Southwest the frijole (*Phaseolus* sp.) is a part of the daily food of the Mexicans or natives of Spanish-Indian descent. Carob (*Ceratonia siliqua*), familiarly known as "St. John's bread," lablab bean (*Dolichos lablab*), mungo bean (*Phaseolus mungo*), asparagus bean (*Dolichos susquepedalis*), and other varieties are common articles of diet in oriental countries and are used to a limited extent in the United States by the Chinese or other residents of foreign birth or extraction.

The legumes are all very rich in nutritive ingredients. Even the unripe fruits of edible podded varieties, such as string beans and sugar peas, which are much esteemed, equal or surpass in composition other green vegetables. The more mature seeds, the so-called shelled

beans and peas, which are also quite extensively eaten, contain as much carbohydrates and more protein than most of the matured vegetable foods, as potatoes. The dried legumes, which are the most abundantly used, surpass all other forms of vegetable food and even most animal foods in richness of protein, while at the same time they contain nearly as much carbohydrates as the cereals.

The total quantity of legumes consumed in this country, though perhaps somewhat less than in European and Asiatic countries, is quite appreciable. In an average of nearly 400 family dietary studies made in connection with the nutrition investigations of the Office of Experiment Stations, dried legumes comprised 1 per cent of the total quantity of food material consumed and supplied nearly 3 per cent of the total protein and a little less than 2 per cent of the total carbohydrates of the diet. They are used, however, more in some regions and under some circumstances than in others. In lumber camps, for example, beans are a very important article of the diet. They supplied upward of 20 per cent of the protein and 10 per cent of the energy of the total food consumed by lumbermen in a camp in Maine in which dietary studies were recently made.^a

DIGESTIBILITY OF LEGUMES.

The richness of the legumes in nutritive constituents does not alone determine their nutritive value. For this it is necessary to know also their digestibility, i. e., the ease and especially the completeness with which their nutrients may be digested and absorbed by the body. Some investigations of the digestibility of legumes have been made during the past thirty years, but in view of their importance as food materials our actual knowledge of the subject has not been as extended as is desirable.

With respect to the ease or rapidity of digestion of legumes, definite information based on experimental data is practically wanting. From earlier times practical experience has suggested that these are "heartly food," and it has been commonly believed that they are harder to digest than other foods. There is a general opinion that they are valuable food for active, hard-working people, especially those much out of doors, but are not suited to those with little exercise or to invalids or convalescents. Some persons are distressed after eating beans by an evolution of gas in the intestine, and the beans are accordingly said to be indigestible, since in popular discussion the term digestibility is used in connection with any food with reference to the extent to which one is or is not made conscious of it during or after digestion. Why or under what conditions or to what extent the legumes cause discomfort in digestion is not clearly known. Experiments with animals indicate that the production of

^a U. S. Dept. Agr., Office of Experiment Stations Bul. 149.

gas in the intestine is due to the fermenting action of bacteria upon carbohydrates. The removal of the skins of beans in the process of cooking and the addition of bicarbonate of soda and salt to the water in which the beans are soaked has been found in some cases to aid in decreasing the amount of fermentation. There has been little actual investigation of the subject, but there is considerable reason to believe, principally from practical experience, but also to some extent from experimental evidence, that when eaten in reasonable amount by persons in health the legumes need not cause distress in digestion.

Some attention has been paid to the study of the thoroughness of digestion of legumes. Hoffman^a found in some experiments with men that 47 per cent of the protein of a diet of bread, lentils, and potatoes was excreted as compared with a loss of 18 per cent of an equal amount of meat protein eaten by the same person. Strümpell^b also studied the digestibility of lentils. When he ate about 250 grams of those that had been soaked awhile in water and cooked in the usual manner, about 40 per cent of the protein was excreted. In the same investigation he made experiments with a mixture of lentil and cereal meals, a commercial preparation, which he made into cakes with milk, eggs, and butter. The quantity of protein in the feces from the whole diet was but 10 per cent of that in the legume preparation used. With all allowance for the fact that part of the protein of the preparation was from cereals, and also that the cakes contained considerable animal protein, which may have had a favorable influence on the digestion of that from the legume, the results would indicate that the legume protein was more thoroughly digested when the lentils were ground and specially prepared than when they were eaten whole as usually cooked. These results have frequently been quoted as showing that the method of preparing the legumes has considerable effect upon their absorption.

Strümpell found as a result of several tests that distilled water alone and distilled water containing magnesium phosphate were absorbed by the dried lentils in larger quantities than distilled water containing calcium phosphate, and, though he made no experiments with the lentils thus prepared, he was persuaded that the method of cooking has an important influence upon the digestibility of legumes.

Woroschiloff^c studied the comparative digestibility of the protein of peas and meat. In his experiments with meat he found in a maximum case 10 per cent of the nitrogen of the meat diet in the feces; but in later experiments the quantity was but 8 per cent with

^a Reported by Voit, Sitzber, K. Bayer, Akad. Wiss. Math. Phys. Kl., 1869, pt. II, p. 483.

^b Deut. Arch. Klin. Med., 17 (1876), p. 108.

^c Abs. in Berlin Klin. Wchnschr., 10 (1873), p. 90.

the largest rations of meat and was as low as 4 per cent with smaller rations. In the experiments with peas, on the other hand, the quantity of nitrogen in the feces from the pea diet was in the lowest case 10 per cent and in two other experiments 12 and 17 per cent, respectively.

Rubner^a made experiments with dried hulled peas, cooked for two or three hours, until soft, and then passed through a sieve. The diet consisted simply of this material, salted to taste, and 1 liter of beer a day. In one case the subject ate 960 grams of peas a day, from which he digested 72 per cent of the protein, 25 per cent of the fat, 93 per cent of the carbohydrates, and 64 per cent of the ash. This diet caused the subject great discomfort from formation of gas, and considerable quantities of the peas appeared undigested in the feces. In the second experiment the amount of peas eaten was reduced to 610 grams per day, in which case there was no discomfort. The coefficients of digestibility in this experiment were: Protein, 83 per cent; fat, 36 per cent; carbohydrates, 96 per cent, and ash, 68 per cent. Malfatti^b made two similar experiments with split peas, cooked until they formed a homogenous porridge, and salted. The amount eaten in each case was nearly the same as in Rubner's second experiment, and about a liter of beer a day was drunk. In one case butter was added to the peas, and in the other it was not. The coefficients of digestibility in the two cases were practically identical, averaging: Organic matter, 91 per cent; protein, 86 per cent; carbohydrates, 96 per cent; ash, 62 per cent. In the experiment with butter added the digestibility of the fat was 92 per cent, but the corresponding figure was not given for the experiment without the butter.

Richter^c also reported some experiments in which the digestibility of peas was studied. As in Rubner's experiments, the peas were cooked until soft and then passed through a sieve, but distilled water was used for cooking in one case and hard water in the other. The subject ate about 600 grams of the purée per day. When the peas were cooked in distilled water, the subject digested 93 per cent of the total organic matter, 90 per cent of the protein, 88 per cent of the fat, and 81 per cent of the ash; but when cooked in hard water the coefficients were for total organic matter 91 per cent, protein 83 per cent, fat 59 per cent, and ash 52 per cent. Not only were the peas cooked in distilled water more thoroughly digested, but they caused less digestive disturbance than those cooked in hard water.

The lower digestibility of the protein of the peas cooked in hard water would favor the opinion suggested by Strümpell's results with

^a Ztschr. Biol., 16 (1880), p. 127.

^b Sitzber. K. Akad. Wiss. [Vienna], Math. Naturw. Kl., 89 (1884), pt. III, p. 339.

^c Arch. Hyg., 46 (1903), p. 264.

lentils—that the character of the water in which the legumes are cooked affects their digestibility. This may be due to the effect of various salts upon the legume proteid, the calcium salts of the water that contains lime combining with it to form compounds insoluble in water, and hence not properly softened in cooking. The influence of bicarbonate of soda in improving this condition may be in neutralizing the effect of the lime.

Prausnitz^a carried on a digestion experiment in which the subject for three days partook of a diet consisting chiefly of white beans. These were soaked in water overnight and then cooked in salted water until soft. A small amount of flour browned in fat was mixed with the beans, with the addition of a little vinegar and some of the water in which the beans were cooked. A trifle over 30 per cent of the nitrogen from the diet was excreted in the feces.

Interesting information regarding the digestibility of preparations of legumes in common use in Japan has been made available by Oshima^b in a summary of Japanese nutrition investigations. Two experiments were made with dried beans cooked in shoyu. The skin of the beans was not removed in cooking. In one experiment the quantity of beans eaten was very much larger than in the other and the digestibility in the former case was decidedly lower than in the latter. In the average of the two experiments the coefficient of digestibility for protein was 65 per cent and that for carbohydrates 86 per cent. The figure for fat was too low for consideration. In contrast with the results obtained in experiments with beans themselves are those in a similar experiment with tofu, a soy-bean preparation consisting chiefly of bean proteid precipitated in combination with magnesium and calcium salts. The coefficient of digestibility in this case was for protein 96 per cent, for fat 97 per cent, and for carbohydrates 88 per cent. In another experiment with tofu the coefficient for carbohydrates was 98 per cent and that for fat 95 per cent, but that for protein only 89 per cent. In the latter case the experiment continued but one day, wherefore the results may be less reliable than those of the experiment that continued longer. They do, however, confirm those obtained in the more reliable experiment in showing that the digestibility of the bean preparation was much higher than that of the whole beans. A one-day experiment with yuba, another soy-bean preparation consisting mainly of coagulated bean proteid, gave the following results: For protein 93 per cent, for fat 96 per cent, and for carbohydrates 87 per cent. In a similar experiment with tofu cake, or kara, which is the soy-bean residue remaining from the preparation of tofu, the coefficients of digestibility obtained were for protein 79 per cent, fat 84 per cent,

^a Ztschr. Biol., 26 (1890), p. 227.

^b U. S. Dept. Agr., Office of Experiment Stations Bul. 159.

and carbohydrates 83 per cent. In the average of four experiments in which the diet included rice in addition to tofu the coefficients were for protein 96 per cent, for fat 95 per cent, and for carbohydrates 99 per cent. The results of all these experiments clearly indicate that the digestibility of the protein of the special preparations of the legumes is decidedly greater than that of the legumes merely cooked in their natural condition.

There is one serious objection to the results of experiments such as the majority of those summarized above; the legumes comprised practically the whole of the diet. Their digestibility under such circumstances may or may not be the same as when they are eaten in combination with other food materials. In experiments with other kinds of food it has been commonly found that the digestibility of a given food is greater when it forms a part of a diet of several materials than when it is eaten alone. It is, of course, desirable to know to what extent the nutrients of the legumes are digested when they are eaten in combination with other foods in the ordinary mixed diet. Information of this nature has been only lately obtained. Recently Snyder^a made some digestion experiments of this nature with white or navy beans. The beans were first cooked for twenty minutes in boiling water containing bicarbonate of soda to loosen the skins, which were then removed by rubbing the beans against each other in cold water. The hulled beans were then baked in the usual way, with butter added to supply fat. These were eaten by active, healthy men as a very considerable part of a simple diet of beans, white bread, and milk, thus combining animal and vegetable protein in the diet. Since the digestibility of the nutrients of the bread and milk eaten was fairly well known as a result of previous investigation with these two materials, allowance could be made for them and the digestibility of the nutrients of the legumes alone computed. The results thus obtained in the average of three experiments were, for total dry matter 91 per cent, protein 80 per cent, fat 80 per cent, and carbohydrates 96 per cent. The average digestibility of the total protein, including that from the bread and milk as well as that from the beans, was 88 per cent. In three other experiments in which the same diet was used but with oleomargarine added, the digestibility of the protein averaged also 88 per cent, and in similar experiments in which butter was used in place of the oleomargarine the average digestibility of the protein was 90 per cent. The indication from all these results is that the legume protein was quite uniformly digested.

Snyder^b reports similar experiments with porridge made from dried peas. The peas were thoroughly cooked for twelve hours, at first rapidly over a gas burner and then more slowly in an oven until they were completely disintegrated, forming a porridge or thick soup

^a Minnesota Sta. Bul. 74, p. 121.

^b Minnesota Sta. Bul. 92, p. 267.

containing about 82 per cent water. Each of the subjects ate daily for three days a quantity of the porridge equivalent to about 6 ounces of dry peas. In addition to the porridge the ration included rice, milk, and sugar, but nearly one-third of the protein of the diet was supplied by the peas. The ration gave entire satisfaction and caused no digestive disturbance. The digestibility of the total ration was very uniform for all three subjects, the average coefficients being protein 87 per cent, fat 94 per cent, and carbohydrates 97 per cent, while the availability of the energy was 90 per cent. When allowance was made for the digestibility of the other foods in the ration, the digestibility of the peas alone was protein 80 per cent and carbohydrates 96 per cent.

In another series of experiments,^a the peas porridge in about the same amount as before was eaten with bread and bacon, though the peas furnished a somewhat smaller proportion of the total protein. In this case the average coefficients of digestibility for the entire ration were protein 84 per cent, fat 96 per cent, and carbohydrates 96 per cent, and 87 per cent of the energy was available, the figures agreeing with those obtained with the peas and rice ration.

It is evident from Snyder's work as a whole that when peas are well cooked the nutrients which they supply are very thoroughly digested.

As a part of the previously mentioned studies of the food of Maine lumbermen, Woods and Mansfield^b conducted three digestion experiments with typical members of the crew living on the regular diet of the camp, which consisted of a number of common food materials, but included baked beans in amounts sufficient to supply 22 to 26 per cent of the total protein consumed. The average coefficients of digestibility for the total diet were, protein 85 per cent, fat 97 per cent, carbohydrates 98 per cent, and ash 88 per cent. It was estimated that if the nutrients of the other materials in the diet aside from beans were digested to the same extent as has been found under other circumstances the coefficient of digestibility of the protein of the beans in these experiments was at least 78 per cent.

INVESTIGATIONS HERE REPORTED.

As will be seen from the foregoing summary, which takes account of all the reports of investigations on legumes which have been found on record, our knowledge regarding the digestibility and consequently the nutritive value of legumes as commonly eaten has hitherto been meager. In view of their importance as dietary articles it has seemed desirable to make a thorough investigation of the subject. The present bulletin is a report of seventy-two experiments conducted at the University of Tennessee, in cooperation with the Department of Agriculture, for the purpose of determining the digestibility of different kinds of legumes. Of these experiments eight were made

^a Loc. cit., p. 270.

^b U. S. Dept. Agr., Office of Experiment Stations Bul. 149, p. 36.

with white beans, six with red kidney beans, and the remainder with different varieties of cowpeas.

The general method of investigation was the same in these experiments as in those reported in previous publications of the Office of Experiment Stations.^a The legumes were eaten in combination with other food materials, both animal and vegetable, and the digestibility of the diet as a whole was ascertained from the data regarding the ingredients of the food consumed and those excreted in the feces. The digestibility of the other constituents of the ration aside from the legumes was assumed from the results of previous investigations, or was ascertained for the subjects of these experiments, and that of the legumes themselves was calculated. These conditions are explained in detail beyond.

In a considerable number of the experiments the diet consisted of bread, milk, butter, pork, bananas, and sugar, in addition to the legumes. In no case was the number of food materials larger than this, but in several experiments some of the articles enumerated other than the legumes were omitted from the diet. The object was to have the diet sufficiently palatable to be eaten for a number of days, and so varied that the results obtained regarding the digestibility of legumes might be considered as applicable to the ordinary mixed diet containing legumes, yet sufficiently simple to allow the estimation of the digestibility of the legumes themselves from the data obtained with the total diet. The foods used were of such nature that but two of them—the pork and the legumes—needed cooking in preparation for the experiments. The legumes were washed thoroughly and then boiled for several hours, until the water was nearly evaporated. They were usually eaten cold. The pork used was ordinary fat salt pork of fairly uniform composition. When included in the ration it was boiled with the legumes and helped to flavor them, but in the majority of the experiments no pork was used.

All the foods used in connection with these experiments were sampled and analyzed except the bananas. The composition of the bananas used was assumed to be that found by analyses previously made in the laboratory of the University of Tennessee. The methods of analyses were those adopted by the Association of Official Agricultural Chemists,^b with such minor modifications as have been found expedient in this laboratory and by other investigators. The heats of combustion of the samples were determined by means of the bomb calorimeter,^c with certain accessory devices added by the writer to increase the facility of the determination.

The data regarding the composition and heat of combustion of the food materials are given in Table 1.

^a See list on cover.

^b U. S. Dept. Agr., Bureau of Chemistry Bul. 46 revised.

^c Jour. Amer. Chem. Soc., 25 (1903), p. 659.

TABLE 1.—Percentage composition and heats of combustion of food materials used in digestion experiments.

Sample No.	Kind of food.	Water.	Nitrogen.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.	Heat of combustion per gram.
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Calories.</i>
558	Beans, kidney.....	11.25	4.06	25.38	1.41	58.38	3.58	.....
573	Beans, white.....	11.21	2.92	18.25	1.63	64.89	4.02	3.885
574	do.....	11.17	3.70	23.13	1.52	60.20	3.98	3.960
585	Cowpeas, whippoorwill.....	8.08	3.68	23.00	1.35	63.64	3.93	4.071
666	do.....	12.84	3.19	19.94	1.48	62.17	3.57	3.908
724	do.....	8.36	3.43	21.44	1.70	64.74	3.76	4.040
601	Cowpeas, clay.....	13.37	3.71	23.19	1.45	58.49	3.50	3.915
679	do.....	10.77	3.51	21.94	1.78	61.79	3.72	3.913
618	Cowpeas, lady.....	11.32	4.08	25.50	1.73	57.88	3.57	4.023
711	do.....	10.27	3.58	22.38	1.75	62.15	3.45	3.922
749	do.....	10.05	3.80	23.75	1.75	60.94	3.51	3.997
559	Milk.....	86.54	.54	3.38	4.25	4.94	.89	.....
603	do.....	86.16	.47	2.94	4.48	5.65	.77	.803
620	do.....	86.10	.54	3.38	4.70	5.05	.77	.755
668	do.....	85.83	.50	3.13	5.29	5.06	.69	.839
681	do.....	85.61	.50	3.13	5.65	4.89	.72	.866
713	do.....	83.65	.61	3.81	6.94	4.91	.69	1.014
726	do.....	85.65	.51	3.19	5.27	5.26	.63	.872
560	Butter.....	9.35	.19	1.20	86.23	.....	3.22	.....
576	do.....	13.49	.14	.85	81.06	.....	4.60	7.187
587	do.....	11.36	.14	.86	85.38	.....	2.70	7.892
604	do.....	14.30	.28	1.72	78.68	.....	5.05	7.040
621	do.....	16.14	.24	1.51	78.00	.....	4.35	6.965
635	do.....	14.76	.21	1.31	80.56	.....	3.37	7.105
669	do.....	6.74	.22	1.37	89.10	.....	2.79	8.058
682	do.....	10.56	.10	.65	85.08	.....	3.71	7.820
714	do.....	11.79	.20	1.23	84.87	.....	2.11	7.866
727	do.....	14.10	.26	1.63	82.88	.....	1.45	7.669
561	Bread, wheat.....	33.45	1.58	9.86	.75	54.77	1.17	.....
575	do.....	32.62	1.71	10.70	1.08	54.38	1.22	3.011
586	do.....	33.17	1.76	11.00	.77	53.92	1.14	2.992
602	do.....	34.03	1.54	9.66	.66	54.70	.95	2.917
619	do.....	32.74	1.75	10.92	.41	54.67	1.26	2.953
667	do.....	30.57	1.53	9.53	.90	58.05	.95	3.077
680	do.....	27.56	1.55	9.86	.94	60.66	.98	3.176
712	do.....	31.64	1.53	9.56	.66	57.27	.87	3.002
725	do.....	31.48	1.54	9.60	.86	57.22	.84	3.025
605	Salt pork.....	7.20	.56	3.51	86.01	.....	3.28	8.220
622	do.....	11.31	.67	4.20	80.44	.....	4.05	7.401
670	do.....	3.52	.76	4.76	90.81	.....	2.38	8.585
715	do.....	7.59	.68	4.23	84.20	.....	3.55	8.090
206	Bananas.....	77.16	.20	1.26	.72	20.14	.72	.898
750	Composite.....	64.84	.76	4.78	3.86	25.61	.91	1.664

The subjects of the experiments were all young men in good physical condition, with normal appetites and digestive functions. During the experimental periods they followed their usual routine of life, the only change being in the character of their diet. It was intended that the ration should include the different food materials in such amount that the nutritive value of the diet would be not far from the common standard for a man at light to moderate muscular work, 112 grams of protein and 3,000 calories of energy per day.

Each of the experiments continued four days, similar or corresponding experiments with two or three subjects running simultaneously. On the evening preceding the first day of each experiment a supper of bread and milk was eaten in order to give the feces a characteristic consistency. Just before the first breakfast of an experiment a capsule containing lampblack was administered to each subject to assist in the demarcation of the feces. A similar demarcation was also made when the experimental period was ended. In this way a very satisfactory separation of the feces pertaining to each experiment was obtained. The total quantity of feces for each experiment was dried and ground for analysis and was analyzed in the

same manner as the foods. The data regarding the composition and heat of combustion of the feces are given in Table 2. These are for the water-free feces in each case, and the weights of feces given in the tables of the experiments beyond are likewise those of water-free feces.

TABLE 2.—Composition and heat of combustion of water-free feces.

Sam- ple No.	Feces from—	Nitrogen.	Protein (N×6.25).	Fat.	Carbo- hydrates.	Ash.	Heat of combustion per gram.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Calories.</i>
562	Experiment No. 233.	6.80	42.48	5.54	39.83	12.15	4.899
563	Experiment No. 234.	7.02	43.90	5.12	39.96	11.02	4.857
564	Experiment No. 235.	6.01	37.59	10.52	39.87	12.02	4.859
566	Experiment No. 236.	7.11	44.43	9.51	34.34	11.72	4.893
567	Experiment No. 237.	6.83	42.68	5.48	40.96	10.88	4.930
568	Experiment No. 238.	6.50	40.62	7.89	40.28	11.21	4.832
570	Experiment No. 240.	7.28	45.47	7.16	34.59	12.78	4.957
571	Experiment No. 239.	6.59	41.15	5.83	39.33	13.69	4.925
577	Experiment No. 334.	6.69	41.81	9.88	35.25	13.06	4.974
578	Experiment No. 335.	5.94	37.14	8.63	42.83	11.40	4.899
579	Experiment No. 336.	5.92	37.07	8.71	41.59	12.63	4.857
581	Experiment No. 337.	7.08	44.27	9.40	29.16	17.17	4.927
582	Experiment No. 338.	6.26	39.14	9.92	35.98	14.96	4.939
583	Experiment No. 339.	6.54	40.85	11.02	30.94	17.19	4.859
588	Experiment No. 340.	5.94	37.14	5.18	48.51	9.17	4.893
589	Experiment No. 341.	5.98	37.34	4.98	48.96	8.72	4.930
590	Experiment No. 342.	5.46	34.11	4.15	52.92	8.82	4.832
592	Experiment No. 343.	6.09	38.04	6.01	46.28	9.67	4.957
593	Experiment No. 344.	6.32	39.51	4.03	47.25	9.21	4.925
594	Experiment No. 345.	6.59	41.18	6.04	42.98	9.80	4.974
606	Experiment No. 346.	5.13	32.05	21.17	28.77	18.01	5.280
607	Experiment No. 347.	5.96	37.24	27.30	22.68	12.78	5.745
608	Experiment No. 348.	4.71	29.45	24.07	31.28	15.20	5.575
610	Experiment No. 349.	5.21	32.56	12.46	40.29	14.69	5.034
611	Experiment No. 350.	6.33	39.54	12.17	37.42	10.87	5.191
612	Experiment No. 351.	5.23	32.71	11.24	42.99	13.06	4.985
614	Experiment No. 352.	6.20	38.77	6.31	42.50	12.42	4.828
615	Experiment No. 353.	6.49	40.58	6.10	43.08	10.24	4.956
616	Experiment No. 354.	5.45	34.03	5.01	50.02	10.94	4.758
623	Experiment No. 355.	4.76	29.74	23.04	28.06	19.16	5.485
624	Experiment No. 356.	5.86	36.61	28.13	16.62	18.64	5.696
625	Experiment No. 357.	4.81	30.04	20.16	36.03	13.77	5.455
627	Experiment No. 358.	5.93	37.09	18.88	26.04	17.99	5.114
628	Experiment No. 359.	6.62	41.35	12.59	33.53	12.53	5.110
629	Experiment No. 360.	6.25	39.08	15.95	29.88	15.09	5.106
631	Experiment No. 361.	6.32	39.42	12.69	29.62	17.27	4.916
632	Experiment No. 362.	6.88	43.01	10.52	33.26	13.21	4.924
633	Experiment No. 363.	6.21	38.82	11.06	34.42	15.70	4.806
636	Experiment No. 364.	5.25	32.83	23.58	28.91	14.68	5.450
637	Experiment No. 365.	5.33	33.29	21.10	28.55	17.06	5.188
639	Experiment No. 366.	5.99	37.45	11.94	36.87	13.74	5.006
640	Experiment No. 367.	5.61	35.03	13.12	35.48	16.37	4.893
671	Experiment No. 626.	5.92	37.02	18.73	28.32	15.93	5.398
672	Experiment No. 627.	5.04	31.53	26.33	25.89	16.25	5.667
673	Experiment No. 628.	5.27	32.92	25.46	26.09	15.53	5.627
675	Experiment No. 629.	6.09	38.09	4.59	45.56	11.76	4.931
676	Experiment No. 630.	6.04	37.77	7.63	42.66	11.94	4.996
677	Experiment No. 631.	5.63	35.20	9.10	43.59	12.11	4.947
683	Experiment No. 632.	5.23	32.68	20.23	30.64	16.45	5.416
684	Experiment No. 633.	5.09	32.02	21.38	30.28	16.32	5.489
685	Experiment No. 634.	5.23	32.66	22.04	29.72	15.58	5.405
687	Experiment No. 635.	5.65	35.31	7.77	46.00	10.92	4.813
688	Experiment No. 636.	5.96	37.22	9.15	41.69	11.94	4.827
689	Experiment No. 637.	5.21	32.55	8.29	47.34	11.82	4.710
716	Experiment No. 638.	4.79	29.98	23.24	27.46	19.32	5.261
717	Experiment No. 639.	4.98	31.13	20.75	28.75	19.37	5.157
718	Experiment No. 640.	4.06	25.40	27.51	27.28	19.81	5.655
720	Experiment No. 641.	5.56	34.72	12.23	36.19	16.86	4.824
721	Experiment No. 642.	5.94	37.13	7.97	40.33	14.57	4.773
722	Experiment No. 643.	5.70	35.63	12.83	39.01	12.53	4.988
728	Experiment No. 644.	4.67	29.17	24.22	27.37	19.24	5.309
729	Experiment No. 645.	5.26	32.86	17.74	30.38	19.02	5.315
730	Experiment No. 646.	3.91	23.42	24.09	34.70	17.79	5.955
732	Experiment No. 647.	5.24	32.73	6.57	48.27	12.43	4.787
733	Experiment No. 648.	6.01	37.54	5.64	44.94	11.88	4.836
734	Experiment No. 649.	5.47	34.21	6.00	49.81	9.98	4.781
751	Experiment No. 650.	5.55	34.59	19.62	30.45	15.34	5.470
752	Experiment No. 651.	5.36	33.48	12.80	36.84	16.88	5.175
753	Experiment No. 652.	4.34	27.15	16.97	37.32	18.56	5.452
755	Experiment No. 653.	6.25	39.04	13.03	32.60	15.33	4.992
756	Experiment No. 654.	6.42	40.13	7.84	38.00	14.03	4.901
757	Experiment No. 655.	6.12	38.23	12.08	37.12	12.57	4.987

In order to ascertain the availability of the energy from a given diet, it is necessary to know not only the energy of the food eaten and that of the feces excreted, but also that of the incompletely oxidized residues from protein that are excreted in the urine. For this reason the urine was collected in the various experiments, and its nitrogen content and heat of combustion were determined. In some instances these data were determined for each day of the experiment and in other cases on a composite sample of the urine for the four days. The total amount, nitrogen content, and heat of combustion of the urine in the various experiments are shown in Table 3.

TABLE 3.—*Amounts, composition, and heat of combustion of urine.*

Sample number.	Experiment number.	Amount.	Nitrogen.		Heat of combustion per gram.
			Proportion.	Amount.	
		<i>Grams.</i>	<i>Per cent.</i>	<i>Grams.</i>	<i>Calories.</i>
565.....	233	1,297	1.13	14.66	0.079
		1,028	1.61	16.55	.127
		1,017	1.71	17.39	.117
		915	1.69	15.46	.109
		1,022	1.12	11.45	.077
565a.....	234	1,037	1.21	12.55	.094
		765	1.43	10.94	.108
		1,030	1.29	13.29	.084
		738	1.42	10.39	.100
565b.....	235	722	1.42	10.25	.107
		670	1.38	9.25	.112
		740	1.51	11.25	.108
		969	1.60	15.50	.106
569.....	236	1,162	1.38	16.04	.092
		1,070	1.47	15.73	.092
		1,430	1.13	16.16	.074
		1,350	1.30	17.55	.083
569a.....	237	1,065	1.57	16.72	.103
		976	1.67	16.30	.114
		1,110	1.55	17.21	.100
		648	1.52	9.85	.111
569b.....	238	790	1.37	10.82	.111
		815	1.41	11.49	.106
		667	1.63	10.87	.119
		1,249	1.25	15.61	.086
572.....	239	1,194	1.14	13.61	.081
		1,065	1.39	14.80	.091
		1,030	1.44	14.83	.095
		890	1.53	13.62	.083
572a.....	240	928	1.63	15.13	.097
		982	1.50	14.73	.083
		1,250	1.25	15.68	.082
580.....	334	4,643	.95	44.11	.078
580a.....	335	3,463	1.28	44.33	.095
580b.....	336	3,794	1.18	44.77	.102
584.....	337	6,236	.84	52.83	.067
584a.....	338	4,736	1.31	62.04	.096
584b.....	339	4,346	1.32	57.37	.100
591.....	340	5,464	1.00	54.64	.067
591a.....	341	5,042	1.14	57.48	.085
591b.....	342	4,627	1.05	48.58	.072
595.....	343	7,753	.76	58.92	.053
595a.....	344	5,469	1.03	56.42	.076
595b.....	345	5,409	.95	51.39	.073
609.....	346	942	1.94	18.27	.....
		1,982	.80	15.86	.....
		2,070	.55	11.39	.....
		1,810	.70	12.67	.....
Total.....		6,804	.....	58.19	.059
609a.....	347	802	.87	6.98	.....
		1,153	1.05	12.11	.....
		1,134	1.08	12.25	.....
		1,409	1.00	14.09	.....
Total.....		4,498	.....	45.43	.078

TABLE 3.—*Amounts, composition, and heat of combustion of urine—Continued.*

Sample number.	Experi- ment number.	Amount.	Nitrogen.		Heat of combustion per gram.
			Proportion.	Amount.	
		Grams.	Per cent.	Grams.	Calories.
609b.....	348	1,351	0.74	10.00	.....
		887	1.15	10.20	.....
		854	1.22	10.42	.....
		902	1.21	10.91	.....
Total.....		3,994	.....	41.53	0.083
613.....	349	1,984	.87	17.26	.....
		2,870	.53	15.21	.....
		1,814	.74	13.42	.....
		2,588	.59	15.27	.....
Total.....		9,256	.....	61.16	.052
613a.....	350	1,573	.99	15.57	.....
		1,152	1.19	13.71	.....
		1,512	1.02	15.42	.....
		1,406	1.07	15.04	.....
Total.....		5,637	.....	59.74	.094
613b.....	351	1,144	1.07	12.24	.....
		1,390	.90	12.51	.....
		1,048	1.19	12.47	.....
		1,088	1.13	12.29	.....
Total.....		4,670	.....	49.51	.082
617.....	352	2,674	.65	17.38	.....
		2,419	.70	16.93	.....
		2,030	.86	17.46	.....
		2,227	.80	17.82	.....
Total.....		9,350	.....	69.59	.053
617a.....	353	1,414	1.00	14.14	.....
		2,259	.81	18.30	.....
		1,970	.87	17.14	.....
		1,380	1.12	15.46	.....
Total.....		7,023	.....	65.04	.085
617b.....	354	1,352	1.04	14.06	.....
		1,422	1.07	15.22	.....
		1,271	1.31	13.65	.....
		1,479	1.11	16.42	.....
Total.....		5,524	.....	59.35	.077
626.....	355	1,024	.73	7.48	.....
		1,337	.58	7.75	.....
		1,317	.55	7.24	.....
		1,978	.71	14.04	.....
Total.....		5,656	.....	36.51	.064
626a.....	356	1,096	1.21	13.25	.....
		1,796	.43	7.72	.....
		1,558	.54	8.41	.....
		1,791	.44	7.88	.....
Total.....		6,241	.....	37.27	.084
626b.....	357	977	.46	4.49	.....
		806	.89	7.17	.....
		633	1.24	7.85	.....
		713	1.09	7.77	.....
Total.....		3,129	.....	27.28	.109
630.....	358	2,671	.57	15.22	.....
		2,568	.56	14.38	.....
		2,430	.60	14.58	.....
		2,468	.61	15.05	.....
Total.....		10,137	.....	59.23	.043

TABLE 3.—*Amounts, composition, and heat of combustion of urine*—Continued.

Sample number.	Experiment number.	Amount.	Nitrogen.		Heat of combustion per gram.
			Proportion.	Amount.	
		<i>Grams.</i>	<i>Per cent.</i>	<i>Grams.</i>	<i>Calories.</i>
630a.....	359	1,595	1.18	18.82	.....
		1,133	1.23	13.94	.....
		1,305	1.27	16.57	.....
		1,362	1.27	17.29	.....
Total.....		5,395	.....	66.62	0.086
630b.....	360	1,047	1.02	10.68	.....
		1,366	1.00	13.66	.....
		1,136	.99	11.25	.....
		1,306	.98	12.80	.....
Total.....		4,855	.....	48.39	.073
634.....	361	2,486	.73	18.15	.....
		2,432	.75	18.24	.....
		2,181	.84	18.32	.....
		2,413	.75	18.10	.....
Total.....		9,512	.....	72.91	.064
634a.....	362	1,522	1.18	17.96	.....
		1,940	1.04	20.20	.....
		1,815	.97	17.31	.....
		1,821	1.03	18.76	.....
Total.....		7,098	.....	74.23	.080
634b.....	363	1,206	1.38	16.63	.....
		1,267	1.30	16.47	.....
		1,291	1.35	17.43	.....
		1,634	1.09	17.81	.....
Total.....		5,398	.....	68.34	.095
638.....	364	1,422	1.12	15.93	.....
		1,422	1.16	16.50	.....
		1,522	1.05	15.98	.....
		1,108	1.39	15.40	.....
Total.....		5,474	.....	63.81	.116
638a.....	365	1,400	1.07	14.98	.....
		1,082	1.23	13.31	.....
		1,049	1.29	13.53	.....
		787	1.66	13.06	.....
Total.....		4,318	.....	54.88	.116
641.....	366	1,406	.95	13.36	.....
		1,521	1.14	17.34	.....
		1,427	1.39	19.84	.....
		1,064	1.51	16.07	.....
Total.....		5,418	.....	66.61	.099
641a.....	367	1,645	1.04	17.11	.....
		1,550	1.00	15.50	.....
		1,424	1.23	17.52	.....
		1,450	1.18	17.11	.....
Total.....		6,069	.....	67.24	.095
674.....	626	3,714	1.20	44.57	.099
674a.....	627	3,208	1.49	47.80	.118
674b.....	628	3,148	1.57	49.42	.144
678.....	629	4,115	1.31	53.91	.101
678a.....	630	3,676	1.48	54.10	.111
678b.....	631	4,497	1.39	62.51	.106
686.....	632	4,256	.88	37.45	.077
686a.....	633	2,819	1.02	29.75	.116
686b.....	634	3,417	.74	29.29	.095
690.....	635	5,469	.74	40.47	.097
690a.....	636	3,761	1.37	51.53	.093
690b.....	637	4,607	1.24	57.13	.073
719.....	638	3,465	1.38	47.82	.104
719a.....	639	3,310	1.27	42.04	.100
719b.....	640	4,525	1.31	59.28	.099
723.....	641	3,896	1.66	64.67	.123

TABLE 3.—*Amounts, composition, and heat of combustion of urine—Continued.*

Sample number.	Experiment number.	Amount.	Nitrogen.		Heat of combustion per gram.
			Proportion.	Amount.	
		<i>Grams.</i>	<i>Per cent.</i>	<i>Grams.</i>	<i>Calories.</i>
723a.....	642	3,956	1.41	55.78	0.109
723b.....	643	5,292	1.25	65.15	.092
731.....	644	2,805	1.60	44.88	.133
731a.....	645	3,106	1.14	35.41	.093
731b.....	646	4,617	1.13	52.17	.095
735.....	647	3,111	1.49	46.35	.134
735a.....	648	4,217	1.20	50.60	.110
735b.....	649	4,807	1.10	52.88	.085
754.....	650	3,586	1.40	50.20	.106
754a.....	651	4,706	.96	45.18	.070
754b.....	652	4,794	1.17	56.09	.085
758.....	653	5,062	1.47	74.41	.121
758a.....	654	6,247	.99	61.84	.078
758b.....	655	6,021	1.30	78.27	.107

EXPERIMENTS WITH KIDNEY BEANS.

Eight experiments were made with kidney beans; two sets of three experiments each, and one of two. There were slight variations in the details of the different sets.

EXPERIMENTS NOS. 233-235.

These three experiments began March 26, 1901. The subjects were all chemists in connection with the work in this laboratory. Hl. was 31 years old and weighed 148 pounds;^a Hr. was 24 years old and weighed 124 pounds; S. was 19 years old and weighed 131 pounds. The diet consisted of a basal ration of bread, milk, butter, bananas, and sugar, supplemented by the beans. The quantities of the foods in the basal ration were uniform for all three subjects. Hr. and S. also ate the same quantity of beans, which was sufficient to supply 51 per cent of the total organic matter of the ration; but Hl. ate 50 per cent more beans, or enough to supply 61 per cent of the total organic matter. The data regarding the total amount of food eaten, the quantities of nutrients supplied, and the digestibility of the total diet and of the beans alone, are shown in Table 4. The amount of beans given in this and all other corresponding tables is the weight of uncooked beans. The weighed quantity of beans for each subject was cooked separately.

^a In all the experiments the weight is that of the subject without clothing.

TABLE 4.—Data of digestion experiments Nos. 233–235.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.
<i>Experiment No. 233, subject Hl.</i>							
	Basal ration:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
561	Bread.....	480	314	47	4	263	6
559	Milk.....	800	101	27	34	40	7
560	Butter.....	60	53	1	52	.....	2
206	Bananas.....	1,200	266	15	9	242	9
	Sugar.....	80	80	.....	.....	80	.....
	Total basal ration.....		814	90	99	625	24
558	Kidney beans.....	1,500	1,278	381	21	876	54
	Total ration.....		2,092	471	120	1,501	78
562	Feces.....	250	220	106	14	100	30
	Amount digested from total ration.....		1,872	365	106	1,401	48
	Amount digested from kidney beans.....		1,105	284	13	808	.....
	Per cent digested from total ration.....		89	77	88	93	62
	Per cent digested from kidney beans.....		86	75	62	92	.....
<i>Experiment No. 234, subject Hr.</i>							
	Total basal ration as in experiment No. 233.....		814	90	99	625	24
558	Kidney beans.....	1,000	852	254	14	584	36
	Total ration.....		1,666	344	113	1,209	60
563	Feces.....	186	166	82	10	74	20
	Amount digested from total ration.....		1,500	262	103	1,135	40
	Amount digested from kidney beans.....		733	181	10	542	.....
	Per cent digested from total ration.....		90	76	91	94	67
	Per cent digested from kidney beans.....		86	71	71	93	.....
<i>Experiment No. 235, subject S.</i>							
	Total ration as in experiment No. 234.....		1,666	344	113	1,209	60
564	Feces.....	152	134	57	16	61	18
	Amount digested from total ration.....		1,532	287	97	1,148	42
	Amount digested from kidney beans.....		755	206	4	555	.....
	Per cent digested from total ration.....		92	83	86	95	70
	Per cent digested from kidney beans.....		89	81	25	95	.....

The amounts of nutrients digested from the whole diet were computed, as previously stated, by deducting the constituents of the total feces from the corresponding ingredients of the total ration. To compute the digestibility of the nutrients of the beans alone, it was assumed that the nutrients of the foods in the basal ration would be digested in the same proportion as has been found in previous investigation with these materials. The factors assumed for the digestibility of the nutrients of the foods other than legumes are here given.

TABLE 5.—Assumed coefficients of digestibility of nutrients in different foods.^a

Kind of food.	Protein.	Fat.	Carbohydrates.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Bread.....	88	90	98
Milk and butter.....	97	95	98
Fork.....	98	98	.....
Bananas.....	85	90	90
Sugar.....	.....	.....	98

^a Connecticut (Storrs) Sta. Rpt. 1899, p. 83.

The method of computation is simple. For illustration, in experiment No. 233 there were 47 grams of protein in bread, of which 88 per cent, or 41 grams, were assumed to be digested; 28 grams of protein in the milk and butter, of which 97 per cent, or 27 grams, were digested; and 15 grams of protein in bananas, of which 85 per cent, or 13 grams, were digested. The bread, milk, butter, and bananas eaten with the beans therefore supplied 81 grams of digestible protein. There were in the total ration 365 grams of digestible protein (i. e., 471 grams eaten, less 106 grams in the feces). Deducting from this the 81 grams from the food other than beans would leave 284 grams of digestible protein from the beans, which equals 75 per cent of the 381 grams of protein in the total quantity of beans eaten. The digestibility of the carbohydrates and fat of the beans alone was computed in the same way.

There is an undesirable range in the coefficients of digestibility of protein of the beans alone; from 71 per cent with Hr. to 81 per cent with S., both on the same diet. Hl., who had the same basal ration as these two subjects but half as much more beans, digested 75 per cent of the bean protein. The coefficients for carbohydrates of the beans were fairly uniform—92, 93, and 95 per cent for the three subjects.

The computed coefficients for digestibility of the fat of the beans alone, ranging from 25 to 71 per cent, are decidedly unsatisfactory, and of no special significance. In the experiments with other legumes reported on succeeding pages similar undesirable ranges in the figures for fat are also found. Such results are due very largely to the small amount of this ingredient in the beans, under which condition a slight error in analyses, or in the assumed factor for digestion of fat in the other foods, has a relatively large effect on the computed results for digestion of fat of the beans alone. That the fat of beans is quite thoroughly digested is indicated by the results of experiments by Korontschewsky and Zimmerman^a with bean oil (presumably made from soy beans), such as is used in China for culinary purposes, in which the subjects digested 95 to 100 per cent of the oil. In the present investigations it would probably be fair to assume that the coefficient for the fat of the beans is the same as that for the fat of the total diet.

EXPERIMENTS NOS. 236-238.

Experiments Nos. 236-238 began April 9, 1901. Subject B. in experiment No. 236 was a student 21 years old weighing 162 pounds. The subjects Hl. in No. 237 and S. in No. 238 were the same as in two of the preceding series of experiments. All three subjects had the same amount of bread, butter, bananas, and sugar, but Hl. and S. had milk in addition, the same amount for each. B. and Hl. had the same

^a *Vyestnik Obshch. Hig. Sudeb. i Prakt. Med.*, 1905, May; abs. in *Biochem. Centbl.*, 4 (1905), p. 292.

amount of beans, enough to furnish 53 to 56 per cent of the total organic matter. The quantity of beans eaten by S. was only two-thirds as large, but still enough to supply 43 per cent of the total organic matter. The data of the experiments are given in Table 6.

TABLE 6.—Data of digestion experiments Nos. 236–238.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbo-hydrates.	Ash.
<i>Experiment No. 236, subject B.</i>							
	Basal ration:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
561	Bread.....	720	470	71	5	394	8
560	Butter.....	140	123	2	121	.....	4
206	Bananas.....	1,200	266	15	9	242	9
	Sugar.....	160	160	.....	.....	160	.....
	Total basal ration.....		1,019	88	135	796	21
558	Kidney beans.....	1,500	1,278	381	21	876	54
	Total ration.....		2,297	469	156	1,672	75
566	Feces.....	191	169	85	18	66	22
	Amount digested from total ration.....		2,128	384	138	1,606	53
	Amount digested from kidney beans.....		1,162	307	10	845	.....
	Per cent digested from total ration.....		93	82	88	96	71
	Per cent digested from kidney beans.....		91	81	46	96	.....
<i>Experiment No. 237, subject HI.</i>							
	Basal ration:						
561	Bread.....	720	470	71	5	394	8
559	Milk.....	800	101	27	34	40	7
560	Butter.....	140	123	2	121	.....	4
206	Bananas.....	1,200	266	15	9	242	9
	Sugar.....	160	160	.....	.....	160	.....
	Total basal ration.....		1,120	115	169	836	28
558	Kidney beans.....	1,500	1,278	381	21	876	54
	Total ration.....		2,398	496	190	1,712	82
567	Feces.....	248	221	106	14	101	27
	Amount digested from total ration.....		2,177	390	176	1,611	55
	Amount digested from kidney beans.....		1,114	287	16	811	.....
	Per cent digested from total ration.....		91	79	93	94	67
	Per cent digested from kidney beans.....		88	75	76	93	.....
<i>Experiment No. 238, subject S..</i>							
	Total basal ration as in experiment No. 237.....		1,120	115	169	836	28
558	Kidney beans.....	1,000	852	254	14	584	36
	Total ration.....		1,972	369	183	1,420	64
568	Feces.....	162	144	66	13	65	18
	Amount digested from total ration.....		1,828	303	170	1,355	46
	Amount digested from kidney beans.....		765	200	10	555	.....
	Per cent digested from total ration.....		93	82	93	95	72
	Per cent digested from kidney beans.....		90	79	77	95	.....

Because of the variation in the diet mentioned above, the nutritive value of the total ration was decidedly different for each subject. HI. had 100 grams of protein and 250 grams of carbohydrates more than S., and only 17 grams less fat, yet the digestibility of the total diet was practically identical for both, and the difference in the calculated results for beans alone was negligible. With HI. the digestion of the protein was a little less thorough than with the others, but the agreement in the results for the three subjects is closer than in the preceding series of experiments.

EXPERIMENTS NOS. 239 AND 240.

Experiment No. 239 with the subject Hl. and No. 240 with the subject B. began April 16, 1901. The basal ration in No. 239 included bread, milk, butter, bananas, and sugar. In No. 240 the milk was omitted and the quantities of bread, butter, and sugar were much smaller than those in experiment No. 239. The quantity of beans in the latter case was one-third larger than in the former. The data of these two experiments are given in Table 7.

TABLE 7.—Data of digestion experiments Nos. 239 and 240.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbo-hydrates.	Ash.
<i>Experiment No. 239, subject Hl.</i>							
	Basal ration:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
561	Bread.....	800	523	79	6	438	9
559	Milk.....	800	101	27	34	40	7
560	Butter.....	140	123	2	121	.....	4
206	Bananas.....	1,200	266	15	9	242	9
	Sugar.....	160	160	.....	.....	160	.....
558	Kidney beans.....	1,200	1,022	305	17	700	43
	Total ration.....		2,195	428	187	1,580	72
571	Feces.....	234	202	96	14	92	32
	Amount digested from total ration.....		1,993	332	173	1,488	40
	Amount digested from kidney beans.....		879	222	12	645	.....
	Per cent digested from total ration.....		91	78	92	94	56
	Per cent digested from kidney beans.....		86	73	71	92	.....
<i>Experiment No. 240, subject B.</i>							
	Basal ration:						
561	Bread.....	480	314	47	4	263	6
560	Butter.....	60	53	1	52	.....	2
206	Bananas.....	1,200	266	15	9	242	9
	Sugar.....	80	80	.....	.....	80	.....
558	Kidney beans.....	1,600	1,363	406	23	934	57
	Total ration.....		2,076	468	88	1,519	74
570	Feces.....	223	195	102	16	77	28
	Amount digested from total ration.....		1,881	366	72	1,442	46
	Amount digested from kidney beans.....		1,210	311	11	888	.....
	Per cent digested from total ration.....		91	78	82	95	62
	Per cent digested from kidney beans.....		89	77	48	95	.....

The diet with the larger quantity of beans was somewhat the more thoroughly digested. The results in this case agree fairly well with the most favorable of those obtained in the preceding experiments.

The final results of the eight experiments with red kidney beans, including both the coefficients for the total ration derived from the experimental data actually obtained, and those for the beans alone calculated in the manner previously described, are here summarized.

TABLE 8.—*Summary of results of digestion experiments with red kidney beans.*

Expt. No.	Subject.	Weight of beans eaten.	For total diet.				For beans alone.			
			Total organic matter.	Protein.	Fat.	Carbohydrates.	Total organic matter.	Protein.	Fat.	Carbohydrates.
		<i>Grams.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
233...	Hl.....	1,500	89	77	88	93	86	75	62	92
234...	Hr.....	1,000	90	76	91	94	86	71	71	93
235...	S.....	1,000	92	83	86	95	89	81	25	95
236...	B.....	1,500	93	82	86	96	91	81	46	96
237...	Hl.....	1,500	91	79	93	94	88	75	76	93
238...	S.....	1,000	93	82	93	95	90	79	77	95
239...	Hl.....	1,200	91	78	92	94	86	73	71	92
240...	B.....	1,600	91	78	82	95	89	77	48	95
	Average.....		91	79	89	94	88	77	60	94

The carbohydrates of the beans were quite thoroughly digested, the average coefficient for the eight experiments being 94 per cent. It is noteworthy, too, that this figure is the mean between the minimum, 92 per cent, and the maximum, 96 per cent, showing a fairly close agreement for all the subjects in respect to digestibility of this nutrient. The figures for fat, as already explained, have no significance. The coefficients for protein are, on the whole, quite satisfactory, though in one or two cases the variation is wider than is desirable. The average for the eight experiments is 77 per cent; but if experiment No. 234 with Hr. and No. 239 with Hl. are omitted, the average of the remaining six experiments would be 78 per cent, which is a mean between the maximum and the minimum of the results. Of these six experiments two were with S., in each of which he ate 1,000 grams (2.2 pounds) of the beans, and digested on the average 80 per cent of their protein. Hl. ate in each of two experiments 1,500 grams (3.3 pounds) of the beans, and digested 75 per cent of the protein. The lower figure with the latter subject can hardly be ascribed to the increase in the quantity of beans, because in the two experiments with B., in one of which he ate 1,500 grams (3.3 pounds) and in the other 1,600 grams (over 3.5 pounds) of the beans, the average digestibility of the protein was 79 per cent. In the four experiments with B. and S. the coefficients of digestibility of the protein of the beans averaged 80 per cent.

The average digestibility of the protein of the total ration was but little higher than that for the beans alone. This is due to the fact that 70 to 80 per cent or more of the protein was furnished by beans, and considerable of the remainder was also vegetable protein.

EXPERIMENTS WITH WHITE BEANS.

Six experiments, two with each of three subjects, were made with white beans. In each case the basal ration was larger and the quantity of beans smaller in the second experiment than in the first. The subjects were college students, B., 22 years of age, weighing 148 pounds; H., 19 years of age, weighing 136 pounds, and K., 28 years of age, weighing 151 pounds.

EXPERIMENTS Nos. 334-336.

The first three experiments began simultaneously on November 12, 1901. The basal ration of bread, butter, bananas, and sugar was uniform for each subject. To this was added white beans, with a little pork to flavor them, a weighed quantity of pork being cooked with the beans in each case. Subjects B. and K. ate the same amount of beans, but H. ate 16 per cent more than they did. The beans supplied 64 to 68 per cent of the total organic matter of the ration.

EXPERIMENTS Nos. 337-339.

These experiments began November 16, 1901, without intermission from those preceding. Lampblack was taken before the first breakfast of the present experiments to mark the separation of the feces. In these experiments the basal ration was again uniform for each subject, but the quantity of each constituent was materially increased, except that of bananas, which was the same as before. The amount of beans eaten was reduced 20 per cent below that in the previous experiments, so that they supplied 38 per cent of the total organic matter in the experiments with B. and K. and 44 per cent with H. The data of the six experiments follow:

TABLE 9.—Data of digestion experiments Nos. 334-339.

Ref. No.		Total weight.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
	SMALLER BASAL RATION; LARGER QUANTITY OF BEANS.							
	<i>Experiment No. 331, subject B.</i>							
	Basal ration:	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
575	Bread.....	480	317	51	5	261	6	1,445
576	Butter.....	40	33	.....	33	.....	2	287
206	Bananas.....	1,000	221	13	7	201	7	898
	Sugar.....	80	80	.....	.....	80	.....	317
	Total basal ration.....	.....	651	64	45	542	15	2,947
	Pork.....	71	59	.....	59	.....	3	549
573	White beans.....	1,500	1,271	274	24	973	60	5,828
	Total ration.....	.....	1,981	338	128	1,515	78	9,324
577	Feces.....	194	169	81	19	68	25	961
580	Urine.....	4,643	.....	.....	.....	.....	.....	302
	Amount digested from total ration.....	.....	1,812	257	109	1,447	53	8,001
	Amount digested from white beans.....	.....	1,145	201	12	932	.....	.....
	Per cent digested from total ration.....	.....	91	76	85	96	68	86
	Per cent digested from white beans.....	.....	90	73	50	96	.....	.....

TABLE 9.—Data of digestion experiments Nos. 334-339—Continued.

Ref. No.		Total weight.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
SMALLER BASAL RATION; LARGER QUANTITY OF BEANS—Cont'd.								
<i>Experiment No. 335, subject H.</i>								
	Total basal ration as in experiment No. 334.....	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
573	Pork.....	61	651	64	45	542	15	2,947
	White beans.....	1,750	1,494	319	29	1,136	70	6,799
	Total ration.....		2,186	383	125	1,678	87	10,220
578	Feces.....	206	183	77	18	88	23	1,009
580a	Urine.....	3,463						329
	Amount digested from total ration.....		2,003	306	107	1,590	64	8,882
	Amount digested from white beans.....		1,335	250	10	1,075		
	Per cent digested from total ration.....		92	80	86	95	74	87
	Per cent digested from white beans.....		90	78	34	95		
<i>Experiment No. 336, subject K.</i>								
	Total basal ration as in experiment No. 334.....		651	64	45	542	15	2,947
573	Pork.....	66	55		55		2	512
	White beans.....	1,500	1,271	274	24	973	60	5,828
	Total ration.....		1,977	338	124	1,515	77	9,287
579	Feces.....	181	158	67	16	75	23	879
580b	Urine.....	3,794						387
	Amount digested from total ration.....		1,819	271	108	1,440	54	8,021
	Amount digested from white beans.....		1,151	215	11	925		
	Per cent digested from total ration.....		92	80	87	95	70	86
	Per cent digested from white beans.....		90	78	39	95		
LARGER BASAL RATION; SMALLER QUANTITY OF BEANS.								
<i>Experiment No. 337, subject B.</i>								
	Basal ration:							
575	Bread.....	1,680	1,112	180	18	914	20	5,058
576	Butter.....	120	98	1	97		6	862
206	Bananas.....	1,000	221	13	7	201	7	898
	Sugar.....	160	160			160		633
	Total basal ration.....		1,591	194	122	1,275	33	7,451
573	Pork.....	46	38		38		2	353
574	White beans.....	600	509	110	10	389	24	2,331
	Do.....	600	509	139	9	361	24	2,376
	Total ration.....		2,647	443	179	2,025	83	12,511
581	Feces.....	174	144	77	16	51	30	857
584	Urine.....	6,236						418
	Amount digested from total ration.....		2,503	366	163	1,974	53	11,236
	Amount digested from white beans.....		951	196	11	744		
	Per cent digested from total ration.....		95	83	91	97	64	90
	Per cent digested from white beans.....		93	78	53	99		
<i>Experiment No. 338, subject H.</i>								
	Total basal ration as in experiment No. 337.....		1,591	194	122	1,275	33	7,451
573	Pork.....	46	38		38		2	353
574	White beans.....	700	593	128	11	454	28	2,720
	Do.....	700	594	162	11	421	28	2,772
	Total ration.....		2,816	484	182	2,150	91	13,296
582	Feces.....	212	180	83	21	76	32	1,047
584a	Urine.....	4,736						465
	Amount digested from total ration.....		2,636	401	161	2,074	59	11,794
	Amount digested from white beans.....		1,081	231	9	841		
	Per cent digested from total ration.....		94	83	88	96	65	89
	Per cent digested from white beans.....		91	80	41	96		

TABLE 9.—Data of digestion experiments Nos. 334-339—Continued.

Ref. No.		Total weight.	Total organic matter	Protein (N×0.25).	Fat.	Carbohy- drates.	Ash.	Energy.
	LARGER BASAL RATION; SMALLER QUANTITY OF BEANS—Cont'd.							
	Experiment No. 339, subject K.							
	Total basal ration as in experi- ment No. 337.....	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
	Pork.....	57	1, 591	194	122	1, 275	33	7, 451
573	White beans.....	600	47	47	47	2	2	637
574	Do.....	600	509	110	10	389	24	2, 331
		600	509	139	9	361	24	2, 376
	Total ration.....		2, 656	443	188	2, 025	83	12, 595
583	Feces.....	174	144	71	19	54	30	845
584b	Urine.....	4, 346						435
	Amount digested from total ration		2, 512	372	169	1, 971	53	11, 315
	Amount digested from white beans		957	202	17	738		
	Percent digested from total ration.		95	84	90	97	64	90
	Percent digested from white beans.		94	81	90	97		

In the first three of the above experiments the results for H. and K. were identical, the coefficients of digestibility of the beans being for protein 78 per cent and for carbohydrates 95 per cent, though the former ate a larger quantity of the beans than the latter. B., who ate the same amount of beans as K., digested 96 per cent of the carbohydrates, but only 73 per cent of the protein. In the second three experiments B. again digested slightly more of the carbohydrates than H. or K., and a little less of the protein, but the difference in the latter case was smaller than before. The coefficients in these experiments ranged from 78 to 81 per cent for protein, and from 96 to 99 per cent for carbohydrates. Each one of the subjects digested the nutrients of the beans more thoroughly from the second ration than from the first. This was doubtless due in part to the reduction in the quantity of beans eaten, and in part to the further decrease in the proportion of the total diet comprised by beans resulting from the increase in the other constituents of the ration.

In the average of the results for all six experiments, the coefficient for protein of the beans is 78 per cent and that for carbohydrates 96 per cent. The results of the separate experiments agree quite well with each other and with the average in the case of the carbohydrates; and in the case of the protein three of the figures are identical with the average, and two are a little above it, but one is noticeably below it. If the results of only the last three of the experiments are considered, in which, as explained above, the proportion of beans to other foods in the ration was more nearly like that in ordinary diet, the average digestibility of the beans would be for protein 80 per cent and for carbohydrates 97 per cent. These figures seem more reasonable than the former.

In the experiment by Prausnitz, previously mentioned (p. 11), with beans cooked in water, only 60 per cent of the protein was

digested, but the beans were eaten alone rather than in combination with other food materials. It has been frequently found in experiments with various foods that digestion is more complete when two or more are combined in the diet than when one is eaten alone, which may account for the lower coefficient for protein in his case. Snyder's experiments, to which reference has also been made (p. 12.), were in this respect more comparable with these here reported; but in those the beans were baked, whereas here they were boiled. It is interesting to note that in the average of three experiments his computed results for the beans alone, total organic matter 91 per cent, protein 80 per cent, fat 80 per cent, and carbohydrates 96 per cent, are almost identical with the average of the last three experiments above.

In preparing his beans Snyder removed the skins to render the conditions more favorable to thorough digestion. The fact that the above experiments, in which the beans were eaten with the skins, agree with his does not necessarily imply that such was not the case, because the beans were cooked differently in the two investigations. The effect of different methods of cooking on the digestion of beans is not known.

In investigations ^a with wheat it has been found that flour containing the bran with its large proportion of crude fiber is less digestible than flour without bran. Snyder found by analysis that the skin contained 40 per cent of the total crude fiber of the beans, and only about 3 per cent of the total protein; and in artificial digestion experiments he found the beans without the skin much more thoroughly digested than those with it. Snyder also points out that when the skin is removed part of the germ ordinarily is removed with it, and as fermentation takes place most readily in the nitrogenous material of the skin and the germ, to remove the latter should tend to decrease the production of gas in the intestines, but neither of these points was directly studied in comparative experiments with men.

In the previously mentioned digestion experiments by Woods and Merrill (see p. 13) with Maine lumbermen, the diet contained large proportions of white beans, but it was so widely varied that the estimate of the digestion of the beans alone is somewhat uncertain. Such figures as can be computed suggest that the beans were about as thoroughly digested as in the average of the six experiments above summarized.

In the experiments by Rubner, Malfatti, and Richter, with boiled split peas (see p. 10), even though in all three cases the peas formed the total diet, the results obtained were as high as those here reported with beans. In Snyder's experiments with peas eaten in a simple mixed diet (see p. 12) the digestibility of the peas was no larger than in these three cases mentioned.

^a U. S. Dept. Agr., Office of Experiment Stations Bul. 156.

EXPERIMENTS WITH COWPEAS.

A kind of legume known as the cowpea, which is the "field pea" of the South, but which is in reality not a pea but a bean, has been grown in the Southern States for upward of one hundred and fifty years, the seed having been introduced from India or China. It is not much known in the Northern States, as it will not properly mature there, though it is grown to some extent as a fodder for cattle, from seeds brought from the South. In the Southern States the plant is grown largely as a green manure, but it is used also as a forage plant for animals, and the seeds are used as food for man. Considerable quantities of the cowpea are consumed during the season in different stages of maturity. The young tender pods are prized as "snap beans." The immature seeds are gathered when the pods begin to change color and before they become dry, and are commonly simply cooked in water. The ripe dried seeds preserved for winter use are sometimes boiled, with or without pork, or baked, or made into soup, or prepared in numerous other ways. A recently published bulletin of the Tuskegee Experiment Station^a gives many recipes for preparing cowpeas which have been tested. There are several varieties of cowpeas—"red" and "black" peas, the round "lady" peas, the large "black-eye" and "purple-eye," the variously mottled and speckled "whippoorwill" peas, and many others.

So far as can be learned, no investigations have hitherto been made regarding the digestibility and nutritive value of cowpeas. In connection with the present investigations of legumes, therefore, the author conducted the following fifty-eight experiments with this object in view, the experiments being made with lady, clay, and whippoorwill peas.

EXPERIMENTS WITH WHIPPOORWILL PEAS.

The following eighteen experiments were made in the study of the digestibility of whippoorwill peas. Of this number twelve included the cowpeas in the diet, while the other six were to determine the digestibility of the basal ration without the legumes, as part of the method of procedure described on pages 33-35.

EXPERIMENTS NOS. 340-345.

These six experiments were made with the same subjects and in the same manner as the six experiments with white beans preceding. The first three experiments, Nos. 340-342, began December 4, 1901. The basal ration was uniform for all three subjects, and B. and K. each had the same amount of cowpeas, enough to furnish 66 per cent of the total organic matter of the ration, but the amount eaten by

^aAlabama (Tuskegee) Sta. Bul. 5.

H. supplied 71 per cent. The next three experiments, Nos. 343-345, began December 8, following the others without intermission, lamp-black to mark the separation of feces being taken before the first breakfast of these experiments. In these the amount of cowpeas was reduced 20 per cent by B. and K. and nearly 16 per cent by H. The basal ration was increased uniformly for all three subjects. The data of these two series of experiments are given in Table 10.

TABLE 10.—Data of digestion experiments Nos. 340-345.

Ref. No.		Total weight.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy- drates.	Ash.	Energy.
	SMALLER BASAL RATION; LARGER QUANTITY OF LEGUMES.							
	<i>Experiment No. 340, subject B.</i>							
	Basal ration:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
586	Bread.....	490	316	53	4	259	5	1,436
587	Butter.....	40	34		34		1	316
206	Bananas.....	1,000	221	13	7	201	7	898
	Sugar.....	80	80			80		317
	Total basal ration.....		651	66	45	540	13	2,967
585	Whippoorwill peas.....	1,500	1,320	345	20	955	59	6,107
	Pork.....	31	26		26		1	242
	Total ration.....		1,997	411	91	1,495	73	9,316
588	Feces.....	317	288	118	16	154	29	1,551
591	Urine.....	5,464						366
	Amount digested from total ration.....		1,709	293	75	1,341	44	7,399
	Amount digested from whippoorwill peas.....		1,069	235	6	828		
	Per cent digested from total ration.....		86	71	82	90	60	79
	Per cent digested from whippoorwill peas.....		80	68	30	87		
	<i>Experiment No. 341, subject H.</i>							
	Basal ration as in experiment No. 340.....		651	66	45	540	13	2,967
585	Whippoorwill peas.....	1,900	1,672	437	26	1,209	75	7,735
	Pork.....	39	32		32		1	298
	Total ration.....		2,355	503	103	1,749	89	11,000
589	Feces.....	392	358	146	20	192	34	1,933
591a	Urine.....	5,042						429
	Amount digested from total ration.....		1,997	357	83	1,557	55	8,638
	Amount digested from whippoorwill peas.....		1,353	299	10	1,044		
	Per cent digested from total ration.....		85	71	81	89	62	79
	Per cent digested from whippoorwill peas.....		81	68	40	86		
	<i>Experiment No. 342, subject K.</i>							
	Basal ration as in experiment No. 340.....		651	66	45	540	13	2,967
585	Whippoorwill peas.....	1,500	1,320	345	20	955	59	6,107
	Pork.....	37	31		31		1	288
	Total ration.....		2,002	411	96	1,495	73	9,362
590	Feces.....	314	286	107	13	166	28	1,517
591b	Urine.....	4,627						333
	Amount digested from total ration.....		1,716	304	83	1,329	45	7,512
	Amount digested from whippoorwill peas.....		1,072	246	10	816		
	Per cent digested from total ration.....		86	74	86	89	62	80
	Per cent digested from whippoorwill peas.....		81	71	50	85		

TABLE 10.—Data of digestion experiments Nos. 340–345—Continued.

Ref. No.		Total weight.	Total organic matter.	Protein (N×6.25).	Fat.	Carbohy drates.	Ash.	Energy.
	LARGER BASAL RATION; SMALLER QUANTITY OF LEGUMES.							
	Experiment No. 343, subject B.							
	Basal ration:	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
586	Bread.....	1,680	1,104	185	13	906	19	5,027
587	Butter.....	120	103	1	102		3	947
206	Bananas.....	1,000	221	13	7	201	7	898
	Sugar.....	160	160			160		633
	Total basal ration.....		1,588	199	122	1,267	29	7,505
585	Whippoorwill peas.....	1,200	1,056	276	16	764	47	4,885
	Pork.....	42	35		35		2	326
	Total ration.....		2,679	475	173	2,031	78	12,716
592	Feces.....	267	242	102	16	124	26	1,324
595	Urine.....	7,753						411
	Amount digested from total ration		2,437	373	157	1,907	52	10,981
	Amount digested from whippoorwill peas.....		889	198	10	681		
	Per cent digested from total ration.....		91	79	91	94	67	84
	Per cent digested from whippoorwill peas.....		84	72	62	90		
	Experiment No. 344, subject H.							
	Basal ration as in experiment No. 343.....		1,588	199	122	1,267	29	7,505
585	Whippoorwill peas.....	1,600	1,408	368	22	1,018	63	6,574
	Pork.....	45	37		37		2	344
	Total ration.....		3,033	567	181	2,285	94	14,423
593	Feces.....	309	281	122	13	146	28	1,522
595a	Urine.....	5,468						416
	Amount digested from total ration		2,752	445	168	2,139	66	12,425
	Amount digested from whippoorwill peas.....		1,202	270	19	913		
	Per cent digested from total ration.....		91	78	93	94	70	87
	Per cent digested from whippoorwill peas.....		85	73	86	90		
	Experiment No. 345, subject K.							
	Basal ration as in experiment No. 343.....		1,588	199	122	1,267	29	7,505
585	Whippoorwill peas.....	1,200	1,056	276	16	764	47	4,885
	Pork.....	45	37		37		2	344
	Total ration.....		2,681	475	175	2,031	78	12,734
594	Feces.....	259	234	107	16	111	25	1,288
595b	Urine.....							588
	Amount digested from total ration		2,447	368	159	1,920	53	10,858
	Amount digested from whippoorwill peas.....		897	193	12	694		
	Per cent digested from total ration.....		91	77	91	95	68	85
	Per cent digested from whippoorwill peas.....		85	70	75	91		

These three subjects digested the cowpeas somewhat less thoroughly than they did the white beans, the average of the coefficients in the six experiments above being for protein 70 per cent and for carbohydrates 88 per cent, as compared with 78 and 96 per cent, respectively, for the beans. Here also, as in the experiments with beans, the digestibility of the compounds was somewhat increased by the

reduction of the quantity of legumes and the increase of the other constituents of the ration.

EXPERIMENTS Nos. 626-631.

In these experiments and all that follow, the method of estimating the digestibility of the nutrients of the legumes alone was modified a little from that explained on page 22. Instead of computing the quantities of digestible nutrients contained in the basal ration by use of factors for the several food materials, the digestibility of the total nutrients of the basal ration alone was ascertained by actual experiment, and the results thus obtained employed as factors in the succeeding experiments with the basal ration and the legumes, after the method followed by Bryant and Milner^a in experiments with vegetables. The changes are explained in the following paragraphs.

Experiments Nos. 626-628, which began on February 13, 1903, and continued four days, were with the same subjects, B., H., and K., as in the preceding series. The diet, designated the basal ration, which was uniform for each subject, included bread, milk, butter, pork, bananas, and sugar. The digestibility of this ration was determined in the usual manner.

With no intermission, experiments Nos. 629-631 began on February 17 and continued four days. The diet in these consisted of a basal ration supplemented by whippoorwill peas. The basal ration was composed of the same materials as in the preceding experiments, but the quantity of each was reduced 35 per cent. The quantity of whippoorwill peas added was sufficient to restore most of the energy and much more than the protein removed in the reduction of the basal ration. The total ration was the same for each subject.

The data of these experiments are given in Table 11.

TABLE 11.—Data of digestion experiments Nos. 626-631.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
	BASAL RATION ALONE.							
	<i>Experiment No. 626, subject B.</i>							
	Basal ration:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
667	Bread.....	1,800	1,233	172	16	1,045	17	5,538
668	Milk.....	4,000	539	125	212	202	28	3,356
669	Butter.....	200	181	3	178	.....	6	1,612
670	Pork.....	120	115	6	109	.....	3	1,030
206	Bananas.....	1,400	310	18	10	282	10	1,257
	Sugar.....	200	200	.....	.....	200	.....	792
	Total ration.....		2,578	324	525	1,729	64	13,585
671	Feces.....	91	77	34	17	26	14	491
674	Urine.....	3,714	.....	.....	.....	.....	.....	368
	Amount digested.....		2,501	290	508	1,703	50	12,726
	Per cent digested.....		97	89	97	98	78	94

^aAmer. Jour. Physiol., 10 (1903), p. 81.

TABLE 11.—Data of digestion experiments Nos. 626–631—Continued.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
	DASAL RATION ALONE—Cont'd.							
	Experiment No. 627, subject H.							
	Total ration as in experiment No. 626	Grams. 2,578	Grams. 324	Grams. 525	Grams. 1,729	Grams. 64	Calories. 13,585	
672	Feces	105	88	33	28	17	595	
674a	Urine	3,208					379	
	Amount digested		2,490	291	497	1,702	47	12,611
	Per cent digested		97	90	95	98	73	93
	Experiment No. 628, subject K.							
	Total ration as in experiment No. 626		2,578	324	525	1,729	64	13,585
673	Feces	83	70	27	21	22	13	467
674b	Urine	3,148						453
	Amount digested		2,508	297	504	1,707	51	12,669
	Per cent digested		97	92	96	99	80	93
	BASAL RATION REDUCED AND LEGUMES ADDED.							
	Experiment No. 629, subject B.							
	Basal ration:							
667	Bread	1,170	802	112	11	679	11	3,600
668	Milk	2,600	351	81	138	132	18	2,182
669	Butter	130	118	2	116		4	1,048
670	Pork	78	75	4	71		2	670
206	Bananas	910	201	11	7	183	7	817
	Sugar	130	130			130		515
	Total basal ration		1,677	210	343	1,124	42	8,832
666	Whippoorwill peas	1,100	919	219	16	684	39	4,299
	Total ration		2,596	429	359	1,808	81	13,131
675	Feces	246	217	94	11	112	29	1,213
678	Urine	4,115						419
	Amount digested from total ration		2,379	335	348	1,696	52	11,502
	Amount digested from whippoorwill peas		757	148	15	594	19	
	Per cent digested from total ration		92	78	97	94	64	88
	Per cent digested from whippoorwill peas		82	67	94	85	49	75
	Experiment No. 630, subject H.							
	Total ration as in experiment No. 629		2,596	429	359	1,808	81	13,131
676	Feces	223	196	84	17	95	27	1,114
678a	Urine	3,676						408
	Amount digested from total ration		2,400	345	342	1,713	54	11,609
	Amount digested from whippoorwill peas		783	156	16	611	23	
	Per cent digested from total ration		92	80	95	95	67	92
	Per cent digested from whippoorwill peas		85	71	100	89	59	79
	Experiment No. 631, subject K.							
	Total ration as in experiment No. 629		2,596	429	359	1,808	81	13,131
677	Feces	211	185	74	19	92	26	1,044
678b	Urine	4,497						477
	Amount digested from total ration		2,411	355	340	1,716	55	11,610
	Amount digested from whippoorwill peas		776	162	11	603	21	
	Per cent digested from total ration		93	83	95	95	68	88
	Per cent digested from whippoorwill peas		84	74	70	88	54	79

The calculation of the coefficients of digestibility of the nutrients of legumes alone is simply this: In experiment No. 629, the basal ration supplied 210 grams of protein. According to the results obtained in No. 626, 89 per cent of this, or 187 grams, would be digested. Deducting this from the 335 grams of protein digested from the total ration would leave 148 grams of digestible protein from whippoorwill peas, which is 67 per cent of the total protein of the peas eaten.

The above computation is based on the assumption that the basal ration will not alter in digestibility when part of it is replaced by the legumes. Perhaps this involves some error. It is not altogether impossible that the coefficients for the basal ration should be slightly reduced when the legumes are added, though on the other hand the reduction in the quantity of the basal ration may offset this effect of the addition of the legumes; but the method seems the best that has yet been proposed. If the factors assumed for the reduced basal ration are somewhat too large, this would mean that the computed results for the legumes alone are slightly smaller than they should be; in other words, they are within rather than beyond the truth. It is believed that they are close approximations to the actual values under the conditions of the experiments.

The digestibility of the total ration in the above experiments with whippoorwill peas was slightly better than in the preceding series, doubtless because the quantity of legumes was somewhat smaller, and the basal ration was larger and more varied. The average of the computed results for the whippoorwill peas themselves is for protein 71 per cent and for fat 87 per cent, practically identical with that in experiments Nos. 343-345 with the same subjects. If computed by the use of assumed coefficients for the separate items of the basal ration, the results for legumes alone would be, for protein 69 per cent and for carbohydrates 90 per cent.

EXPERIMENTS Nos. 644-649.

This series of experiments was like the one described above. The subjects were three college students—Fa., 23 years old, weighing 151 pounds; Fx., 25 years old, weighing 143 pounds; and Ky., 26 years old, weighing 188 pounds. The experiments with the basal ration, which was exactly the same as in the corresponding experiments of the previous series, began January 13, 1904. In the experiments with legumes, which began January 17, the basal ration was reduced 40 per cent, and enough whippoorwill peas were added to supply 45 per cent of the total organic matter of the diet. The data of these experiments follow.

TABLE 12.—Data of digestion experiments Nos. 644–649.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
BASAL RATION ALONE.								
<i>Experiment No. 644, subject Fa.</i>								
	Basal ration:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
725	Bread.....	1,800	1,218	173	15	1,030	15	5,445
726	Milk.....	4,000	549	128	211	210	25	3,488
727	Butter.....	200	169	3	166		3	1,534
715	Pork.....	120	106	5	101		4	971
206	Bananas.....	1,400	310	18	10	282	10	1,257
	Sugar.....	200	200			200		792
	Total ration.....		2,552	327	503	1,722	57	13,487
728	Feces.....	96	77	28	23	26	18	510
731	Urine.....	2,805						373
	Amount digested.....		2,475	299	480	1,696	39	12,604
	Per cent digested.....		97	91	95	98	68	93
<i>Experiment No. 645, subject Fx.</i>								
	Total ration as in experiment No. 644.....		2,552	327	503	1,722	57	13,487
729	Feces.....	111	90	36	20	34	21	590
731a	Urine.....	3,106						289
	Amount digested.....		2,462	291	483	1,688	36	12,608
	Per cent digested.....		94	89	96	98	63	93
<i>Experiment No. 646, subject Ky.</i>								
	Total ration as in experiment No. 644.....		2,552	327	503	1,722	57	13,487
730	Feces.....	86	71	20	21	30	15	512
731b	Urine.....	4,617						439
	Amount digested.....		2,481	307	482	1,692	42	12,536
	Per cent digested.....		97	94	96	98	74	93
BASAL RATION REDUCED AND LEGUMES ADDED.								
<i>Experiment No. 647, subject Fa.</i>								
	Basal ration:							
725	Bread.....	1,080	731	104	9	618	9	3,267
726	Milk.....	2,400	329	77	126	126	15	2,093
727	Butter.....	120	101	2	99		2	920
715	Pork.....	72	64	3	61		3	582
206	Bananas.....	840	186	11	6	169	6	754
	Sugar.....	120	120			120		475
	Total basal ration.....		1,531	197	301	1,033	35	8,091
724	Whippoorwill peas.....	1,400	1,230	300	24	906	53	5,656
	Total ration.....		2,761	497	325	1,939	88	13,757
732	Feces.....	315	276	103	21	152	39	1,508
735	Urine.....	3,111						417
	Amount digested from total ration.....		2,485	394	304	1,787	49	11,822
	Amount digested from whippoorwill peas.....		1,008	215	18	775	25	
	Per cent digested from total ration.....		90	79	93	92	56	86
	Per cent digested from whippoorwill peas.....		82	72	75	86	47	75

TABLE 12.—Data of digestion experiments Nos. 644-649—Continued.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
	BASAL RATION REDUCED AND LEGUMES ADDED—Cont'd.							
	<i>Experiment No. 648, subject Fz.</i>							
	Total ration as in experiment No. 647	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
733	Feces	289	2,761	497	325	1,939	88	13,747
735a	Urine	4,217	255	109	16	130	34	1,398
	Amount digested from total ration		2,506	388	309	1,809	54	11,885
	Amount d. gested from whippoorwill peas		1,030	213	20	797	31	
	Per cent digested from total ration		91	78	95	93	61	86
	Per cent digested from whippoorwill peas		84	71	83	88	59	76
	<i>Experiment No. 649, subject Ky.</i>							
	Total ration as in experiment No. 647		2,761	497	325	1,939	88	13,747
734	Feces	373	336	128	22	186	37	1,783
735b	Urine	4,807						409
	Amount digested from total ration		2,425	369	303	1,753	51	11,555
	Amount d. gested from whippoorwill peas		939	184	14	741	28	
	Per cent digested from total ration		88	74	93	90	58	84
	Per cent d. gested from whippoorwill peas		76	61	60	82	53	71

The total diet was not digested quite so thoroughly in these experiments as in the previous series. This may be because the subjects were different or because the quantity of whippoorwill peas was larger and the basal ration correspondingly smaller in the present series. However, two of the subjects, Fa. and Fx., digested the nutrients of the legumes, according to the computed results, about as thoroughly as the subjects of the previous series. Ky. did not digest either the protein or the carbohydrates of the whippoorwill peas nearly as completely as any of the other five subjects. Disregarding the results with this subject, which because of the wide discrepancy seems but fair, the average results for the legumes alone in this series is for protein 71 per cent and for carbohydrates 87 per cent, just the same as in the previous series. Computed in the former manner by assuming coefficients for each constituent of the basal ration, the results for the whippoorwill peas alone would be protein 72 per cent and carbohydrates 86 per cent, a practical agreement with those just stated.

The results of the twelve experiments with whippoorwill peas are here summarized.

TABLE 13.—*Estimated coefficients of digestibility of whippoorwill peas.*

Experiment No.	Subject.	Weight of legumes eaten.	Total organic matter.	Protein.	Fat.	Carbohydrates.
		<i>Grams.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
340.....	B.....	1,500	80	68	30	87
341.....	H.....	1,900	81	68	40	86
342.....	K.....	1,500	81	71	50	85
343.....	B.....	1,200	84	72	62	90
344.....	H.....	1,600	85	73	86	90
345.....	K.....	1,200	85	70	75	91
629.....	B.....	1,100	82	67	94	85
630.....	H.....	1,100	85	71	100	89
631.....	K.....	1,100	84	74	70	88
647.....	Fa.....	1,400	82	72	75	86
648.....	Fx.....	1,400	84	71	83	88
649.....	Ky.....	1,400	76	61	60	82
Average.....			82	70		87

In the average for the twelve experiments the digestibility of the protein of the whippoorwill peas is 70 per cent; but this includes at least one figure that is unusually low. It will be observed that the result in seven of the twelve experiments exceeds 70 per cent, and in one it is the same. A fairer average for the protein would be at least 72 per cent. Likewise in the case of the carbohydrates, the average is 87 per cent; but while the result in one experiment equals that, those in six others exceed it. This would suggest that the average might be placed nearer 90 per cent.

EXPERIMENTS WITH CLAY PEAS.

In the study of the digestibility of clay peas, fifteen experiments were made, in ten of which the legumes formed a considerable portion of the diet, the other five being determinations of the coefficients for the basal ration alone. The details follow.

EXPERIMENTS NOS. 346-354.

These experiments were made with the same subjects, B., H., and K., as in Nos. 340-345 with whippoorwill peas, and the plan of the present experiments was practically the same as that of the previous series. The particular difference is an extra four-day legume period in the present series. The basal ration experiments, Nos. 346-348, began on January 21, 1902. The first legume period, experiments Nos. 349-351, began on January 25. The basal ration was reduced 20 per cent and enough clay peas were added to furnish nearly the same amount of energy as that in the material deducted. The second legume period, experiments Nos. 349-351, began on January 29. In these the original basal ration was reduced 50 per cent, and enough legumes added to restore the energy. Subject B. had the same diet as K. in each case, but H. ate a larger basal ration and more legumes than they. The data of these experiments are shown in Table 14, bringing the results for the basal ration and the first and second legume period together serially for each subject.

TABLE 14.—Data of digestion experiments Nos. 346-354.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
BASAL RATION ALONE.								
<i>Experiment No. 346, subject B.</i>								
	Basal ration:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
302	Bread.....	1,800	1,170	174	12	984	17	5,251
603	Milk.....	4,000	523	118	179	226	31	3,212
604	Butter.....	200	160	3	157		10	1,408
605	Pork.....	120	107	4	103		4	986
206	Bananas.....	1,400	310	18	10	282	10	1,251
	Sugar.....	200	200			200		792
	Total basal ration.....		2,470	317	461	1,692	72	12,906
606	Feces.....	88	72	28	19	25	16	473
609	Urine.....	6,804						401
	Amount digested.....		2,398	289	442	1,667	56	12,032
	Per cent digested.....		97	91	96	98	78	93
BASAL RATION AND CLAY PEAS.								
<i>Experiment No. 349, subject B.</i>								
	Basal ration as in experiment No. 346 reduced 20 per cent.....		1,977	253	369	1,355	58	10,324
601	Clay peas.....	700	681	162	10	409	25	2,741
	Total ration.....		2,558	415	379	1,764	83	13,065
610	Feces.....	225	192	73	28	91	33	1,133
613	Urine.....	9,256						481
	Amount digested from total ration.....		2,366	342	351	1,673	50	11,451
	Amount digested from clay peas.....		459	114		345	5	
	Per cent digested from total ration.....		92	82	93	95	60	88
	Per cent digested from clay peas.....		79	70		84		
<i>Experiment No. 352, subject B.</i>								
	Basal ration as in experiment No. 346 reduced 50 per cent.....		1,235	159	230	846	36	14,453
601	Clay peas.....	1,815	1,509	421	26	1,062	64	7,106
	Total ration.....		2,744	580	256	1,908	100	13,559
614	Feces.....	349	305	135	22	148	43	1,685
617	Urine.....	9,350						496
	Amount digested from total ration.....		2,439	445	234	1,760	57	11,378
	Amount digested from clay peas.....		1,244	300	13	931	29	
	Per cent digested from total ration.....		89	77	91	92	57	84
	Per cent digested from clay peas.....		82	71	50	91	45	
BASAL RATION ALONE.								
<i>Experiment No. 347, subject H.</i>								
	Basal ration:							
602	Bread.....	2,800	1,820	270	18	1,532	27	8,168
603	Milk.....	4,000	523	118	179	226	31	3,212
604	Butter.....	200	160	3	157		10	1,408
605	Pork.....	120	107	4	103		4	986
206	Bananas.....	1,400	310	18	10	282	10	1,257
	Sugar.....	200	200			200		792
	Total basal ration.....		3,120	413	467	2,240	82	15,823
607	Feces.....	137	119	51	37	31	18	787
609a	Urine.....	4,498						351
	Amount digested.....		3,001	362	430	2,209	64	14,685
	Per cent digested.....		96	88	92	98	78	93

TABLE 14.—Data of digestion experiments Nos. 346-354—Continued.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
	BASAL RATION WITH CLAY PEAS.							
	<i>Experiment No. 350, subject H.</i>							
	Basal ration as in experiment No. 347 reduced 20 per cent.	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
601	Clay peas.....	840	2,497 688	330 195	375 12	1,792 491	65 29	12,658 3,289
	Total ration.....		3,195	525	387	2,283	94	15,947
611	Feces.....	201	179	80	24	75	22	1,043
613a	Urine.....	5,643						530
	Amount digested from total ration		3,016	445	363	2,208	72	14,374
	Amount digested from clay peas..		625	155	18	452	21	
	Percent digested from total ration		94	85	94	97	77	60
	Percent digested from clay peas..		89	79		92	72	
	<i>Experiment No. 353, subject H.</i>							
	Basal ration as in experiment No. 347 reduced 50 per cent.		1,560	207	233	1,120	38	7,912
601	Clay peas.....	1,910	1,598	443	28	1,117	69	7,478
	Total ration.....		3,148	650	261	2,237	107	15,390
615	Feces.....	372	334	151	23	160	38	1,844
617a	Urine.....	7,023						597
	Amount digested from total ration		2,814	499	238	2,077	69	12,949
	Amount digested from clay peas..		1,320	317	24	979	39	
	Percent digested from total ration		89	77	91	93	64	84
	Percent digested from clay peas..		83	71	82	88	56	
	BASAL RATION ALONE.							
	<i>Experiment No. 348, subject K.</i>							
	Basal ration:							
602	Bread.....	1,800	1,170	174	12	984	17	5,251
603	Milk.....	4,000	523	118	179	226	31	3,212
604	Butter.....	200	160	3	157		10	1,408
605	Pork.....	120	107	4	103		4	986
206	Bananas.....	1,400	310	18	10	282	10	1,257
	Sugar.....	200	200			200		792
	Total basal ration.....		2,470	317	461	1,692	72	12,906
608	Feces.....	102	86	30	25	32	16	569
609b	Urine.....	3,994						332
	Amount digested.....		2,384	287	436	1,660	56	12,005
	Percent digested.....		96	90	95	98	78	93
	BASAL RATION WITH CLAY PEAS.							
	<i>Experiment No. 351, subject K.</i>							
	Basal ration as in experiment No. 348, reduced 20 per cent.		1,977	253	369	1,355	58	10,324
601	Clay peas.....	700	581	162	10	409	25	2,741
	Total ration.....		2,558	415	379	1,764	83	13,065
612	Feces.....	196	170	64	22	84	26	977
613b	Urine.....	4,670						383
	Amount digested from total ration		2,388	351	357	1,680	57	11,705
	Amount digested from clay peas..		481	123	6	352	12	
	Percent digested from total ration		93	85	94	95	69	60
	Percent digested from clay peas..		83	80	60	86	48	

TABLE 14.—*Data of digestion experiments Nos. 346-354—Continued.*

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
	BASAL RATION WITH CLAY PEAS—Continued.							
	<i>Experiment No. 354, subject K.</i>							
	Basal ration as in experiment No. 348, reduced 50 per cent.....	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
601	Clay peas.....	1,815	1,509	421	229	808	35	6,249
	Total ration.....	2,698	573	255	1,870	99	13,355	
616	Feces.....	358	319	122	18	179	39	1,703
617b	Urine.....	5,524					425	
	Amount digested from total ration.....	2,379	451	237	1,691	60	11,227	
	Amount digested from clay peas.....	5,232	314	19	899	33		
	Percent digested from total ration.....	88	79	93	90	61	84	
	Percent digested from clay peas.....	82	75	73	85	52		

There was considerable variation in the results of similar experiments with different subjects. Thus B. digested 70 per cent of the protein and 84 per cent of the carbohydrates of the beans in the ration with the smaller quantity of legumes, whereas K. digested 80 per cent of the protein and 86 per cent of the carbohydrates from a ration identical with it. H., who ate a larger quantity of legumes, digested 79 per cent of the protein and 92 per cent of the carbohydrates. When the amount of legumes in the ration was increased about two and one-half times, and the basal ration correspondingly decreased, B. digested the same proportion of protein and a little larger proportion of the carbohydrates of the cowpeas than with the smaller amount, but H. and K. digested both the protein and the carbohydrates less thoroughly.

EXPERIMENTS NOS. 632-637.

In the experiments in which the basal ration period was followed by two periods with larger quantities of legumes, the excessive legume diet became distasteful, and examination of the feces indicated that digestion may have been slightly impaired. Accordingly in the present experiments the basal ration period was followed by only one legume period. The experiments with the basal ration alone began February 26, 1903. The diet was uniform for each subject. In the legume period beginning March 2, the basal ration in each case was reduced 40 per cent, and for the material thus removed was substituted enough clay peas to supply above 41 per cent of the total organic matter of the diet. The subjects were three college students, Ba., 20 years old, weighing 146 pounds; G., 24 years old, weighing 146 pounds; and R., 26 years old, weighing 149 pounds. The data of the experiments are given in Table 15.

TABLE 15.—Data of digestion experiments Nos. 632-637.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
BASAL RATION ALONE.								
<i>Experiment No. 632, subject Ba.</i>								
	Basal ration:	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
680	Bread.....	1,800	1,286	177	17	1,092	18	5,717
681	Milk.....	4,000	547	125	226	196	29	3,464
682	Butter.....	200	171	1	170	.....	7	1,564
670	Pork.....	120	115	6	109	.....	3	1,030
206	Bananas.....	1,400	310	18	10	282	10	1,257
	Sugar.....	200	200	.....	.....	200	.....	792
	Total ration.....	.....	2,629	327	532	1,770	67	13,824
683	Feces.....	88	74	29	18	27	14	478
686	Urine.....	4,256	.....	.....	.....	.....	.....	328
	Amount digested.....	.....	2,555	298	514	1,743	53	13,018
	Per cent digested.....	.....	97	91	97	98	79	94
<i>Experiment No. 633, subject G.</i>								
	Total ration as in experiment No. 632.....	.....	2,629	327	532	1,770	67	13,824
684	Feces.....	117	98	37	25	55	19	642
686a	Urine.....	2,819	.....	.....	.....	.....	.....	327
	Amount digested.....	.....	2,531	290	507	1,735	48	12,858
	Per cent digested.....	.....	96	89	95	98	72	93
<i>Experiment No. 634, subject R.</i>								
	Total ration as in experiment No. 632.....	.....	2,629	327	532	1,770	67	13,824
685	Feces.....	85	72	28	19	25	13	450
686b	Urine.....	3,417	.....	.....	.....	.....	.....	325
	Amount digested.....	.....	2,557	299	513	1,745	54	13,043
	Per cent digested.....	.....	97	91	96	98	81	94
BASAL RATION REDUCED AND LEGUMES ADDED.								
<i>Experiment No. 635, subject Ba.</i>								
	Basal ration:							
680	Bread.....	1,080	771	106	10	655	11	3,430
681	Milk.....	2,400	328	75	136	117	17	2,078
682	Butter.....	120	103	1	102	.....	4	938
670	Pork.....	72	68	3	65	.....	2	618
206	Bananas.....	840	186	11	6	169	6	754
	Sugar.....	120	120	.....	.....	120	.....	475
	Total basal ration.....	.....	1,576	196	319	1,061	40	8,293
679	Clay peas.....	1,300	1,111	285	23	803	48	5,087
	Total ration.....	.....	2,687	481	342	1,864	88	13,380
687	Feces.....	300	267	106	23	138	33	1,444
690	Urine.....	5,469	.....	.....	.....	.....	.....	530
	Amount digested from total ration.....	.....	2,420	375	319	1,726	55	11,416
	Amount digested from lady peas.....	.....	893	197	10	686	23	.....
	Per cent digested from total ration.....	.....	90	78	93	93	62	85
	Per cent digested from clay peas.....	.....	80	70	40	85	48	71
<i>Experiment No. 636, subject G.</i>								
	Total ration as in experiment No. 635.....	.....	2,687	481	342	1,864	88	13,380
688	Feces.....	278	244	103	25	116	33	1,342
690a	Urine.....	3,761	.....	.....	.....	.....	.....	350
	Amount digested from total ration.....	.....	2,443	378	317	1,748	55	11,688
	Amount digested from clay peas.....	.....	926	204	14	708	26	.....
	Per cent digested from total ration.....	.....	91	79	93	94	62	87
	Per cent digested from clay peas.....	.....	83	72	60	88	54	78

TABLE 15.—*Data of digestion experiments Nos. 632-637—Continued.*

Ref. No.	Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
BASAL RATION REDUCED AND LEGUMES ADDED—Cont'd.							
<i>Experiment No. 637, subject R.</i>							
Total ration as in experiment No. 635.....	Grams. 2,687	Grams. 481	Grams. 342	Grams. 1,864	Grams. 88	Calories. 13,380	
680 Feces.....	215	190	70	18	102	25	1,013
680b Urine.....	4,607						336
Amount digested from total ration.....	2,497	411	324	1,762	63	12,031	
Amount digested from clay peas.....	973	233	18	712	31		
Per cent digested from total ration.....	93	85	95	94	72	90	
Per cent digested from clay peas.....	88	82	78	90	65	83	

Here also, as in the preceding series with clay peas, there is a considerable variation in results for different subjects. Ba. and 'G. agreed fairly well in thoroughness of digestion of the peas, their range being 70 to 72 per cent for protein and 85 to 88 per cent for carbohydrates; but R. digested 82 per cent of the protein and 90 per cent of the carbohydrates from the very same diet.

The computed results for legumes alone in these nine experiments with clay peas are here summarized.

TABLE 16.—*Estimated coefficients of digestibility of clay peas.*

Experiment No.	Subject.	Weight of legumes eaten.	Total organic matter.	Protein.	Fat.	Carbohydrates.
		Grams.	Per cent.	Per cent.	Per cent.	Per cent.
349.....	B.....	700	79	70		84
350.....	H.....	840	89	79		92
351.....	K.....	700	83	80	60	86
352.....	B.....	1,815	82	71	50	91
353.....	H.....	1,910	83	71	82	88
354.....	K.....	1,815	82	75	73	85
635.....	Ba.....	1,300	80	70	40	85
636.....	G.....	1,300	83	72	60	88
637.....	R.....	1,300	88	82	78	90
Average.....			83	74		88

The average of coefficients for carbohydrates, 88 per cent, is a mean between the maximum and the minimum results in individual experiments, 92 and 84 per cent, respectively. Five of the nine cases equal or surpass the average. The figure therefore seems a fair one. The average for protein, 74 per cent, is a little below the mean between the maximum, 82, and the minimum, 70 per cent. In three cases the results were 79 per cent or over, and in five cases they ranged from 70 to 72 per cent. The range 70 to 80 per cent was found in two duplicate experiments with 700 grams of legumes eaten in each; and an even larger range, 70 to 82 per cent, in two duplicate experiments with 1,300 grams of legumes. But two of the three experiments with

the smaller quantity of legumes gave larger coefficients for protein than five of the six experiments with larger quantities. It seems fair to infer that the increase in the quantity of peas in the diet decreased the thoroughness of digestion of the protein of the peas.

EXPERIMENTS WITH LADY PEAS.

The object of the following experiments was to determine the digestibility of lady peas. In fourteen of the experiments the legumes comprised various proportions of the total diet. The purpose of the other eleven experiments was to determine the digestibility of the diet with which the peas were eaten, in order to compute that of the legumes themselves.

EXPERIMENTS NOS. 355-363.

These experiments were made with the same subjects, B., H., and K., and in the same manner, as experiments Nos. 340-345 (p. 30). The basal ration period began February 21, 1902. In the first legume period, which began February 25, the basal ration was reduced 25 per cent, and was supplemented by lady peas, a sufficient quantity of these being added to bring the total energy of the diet as nearly as practicable the same as that in the original basal ration, without increasing the protein of the diet beyond a certain amount. In the next legume period, beginning March 1, the basal ration was reduced 50 per cent and supplemented by lady peas.

The data of the experiments are given in Table 17.

TABLE 17.—Data of digestion experiments Nos. 355-363.

Rcf. No.		Total weight	Total organic matter	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
	BASAL RATION ALONE.							
	<i>Experiment No. 355, subject B.</i>							
	Basal ration:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
619	Bread.....	1,800	1,188	197	7	984	23	5,315
620	Milk.....	4,000	525	135	188	202	31	3,020
621	Butter.....	200	159	3	156		9	1,393
622	Pork.....	120	102	5	97		5	888
206	Bananas.....	1,400	310	18	10	282	10	1,257
	Sugar.....	200	200			200		792
	Total basal ration.....		2,484	358	458	1,668	78	12,665
623	Feces.....	99	80	29	23	28	19	543
626	Urine.....	5,656						362
	Amount digested.....		2,404	329	435	1,640	59	11,760
	Per cent digested.....		97	92	95	98	76	93

TABLE 17.—Data of digestion experiments Nos. 355-363—Continued.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
BASAL RATION AND LADY PEAS.								
<i>Experiment No. 358, subject B.</i>								
	Basal ration as in experiment No. 355 reduced 25 per cent.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
618	Lady peas	700	1,862 596	267 179	344 12	1,251 405	59 25	9,500 2,816
	Total ration		2,458	446	356	1,656	84	12,316
627	Feces	146	120	54	28	38	26	747
629	Urine	10,137						436
	Amount digested from total ration		2,338	392	328	1,618	58	11,133
	Amount digested from lady peas		539	146	1	392	13	
	Per cent digested from total ration		95	88	92	98	69	90
	Per cent digested from lady peas		90	82		97	52	
<i>Experiment No. 361, subject B.</i>								
	Basal ration as in experiment No. 355 reduced 50 per cent.							
618	Lady peas	1,600	1,243 1,362	180 408	229 28	834 926	37 57	6,334 6,437
	Total ration		2,605	588	257	1,760	94	12,771
631	Feces	219	181	86	30	65	38	1,077
634	Urine	9,512						609
	Amount digested from total ration		2,424	502	227	1,695	56	11,085
	Amount digested from lady peas		1,223	336	9	878	28	
	Per cent digested from total ration		93	85	88	96	60	87
	Per cent digested from lady peas		90	82	34	95	49	
BASAL RATION ALONE.								
<i>Experiment No. 366, subject H.</i>								
	Basal ration:							
619	Bread	2,800	1,848	306	11	1,531	35	8,268
620	Milk	4,000	525	135	188	202	31	3,020
621	Butter	200	159	3	156		9	1,393
622	Pork	120	102	5	97		5	888
206	Bananas	1,400	310	18	10	282	10	1,257
	Sugar	200	200			200		792
	Total basal ration		3,144	467	462	2,215	90	15,618
624	Feces	111	90	41	31	18	21	633
626a	Urine	6,241						524
	Amount digested		3,054	426	431	2,197	69	14,461
	Per cent digested		97	91	93	99	77	93
BASAL RATION AND LADY PEAS.								
<i>Experiment No. 359, subject H.</i>								
	Basal ration as in experiment No. 356 reduced 25 per cent.							
618	Lady peas	840	2,357 715	349 214	347 15	1,661 486	68 30	11,714 3,379
	Total ration		3,072	563	362	2,147	98	15,093
628	Feces	157	138	65	20	53	20	802
630a	Urine	5,395						464
	Amount digested from total ration		2,934	498	342	2,094	78	13,827
	Amount digested from lady peas		639	180	19	450	26	
	Per cent digested from total ration		96	88	94	98	80	92
	Per cent digested from lady peas		89	84	100	93	87	

TABLE 17.—Data of digestion experiments Nos. 355-363—Continued.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
	BASAL RATION AND LADY PEAS—Continued.							
	<i>Experiment No. 362, subject H.</i>							
	Basal ration as in experiment No. 356, reduced 50 per cent.....	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
618	Lady peas.....	2,000	1,702	510	35	1,157	71	8,046
	Total ration.....		3,275	745	266	2,264	115	15,856
632	Feces.....	288	250	124	30	96	38	1,418
634a	Urine.....	7,098						568
	Amount digested from total ration.....		3,025	621	236	2,168	77	13,870
	Amount digested from lady peas.....		1,500	407	21	1,072	43	
	Per cent digested from total ration.....		92	83	89	96	67	87
	Per cent digested from lady peas.....		88	80	60	93	61	
	BASAL RATION ALONE.							
	<i>Experiment No. 367, subject K.</i>							
619	Basal ration:							
	Bread.....	1,800	1,188	197	7	964	23	5,315
620	Milk.....	4,000	1,525	135	188	202	31	3,020
621	Butter.....	200	159	3	156		9	1,393
622	Pork.....	120	102	5	97		5	888
206	Bananas.....	1,400	310	18	10	282	10	1,257
	Sugar.....	200	200			200		792
	Total basal ration.....		2,484	358	458	1,668	78	12,665
625	Feces.....	137	118	41	28	49	19	747
626b	Urine.....	3,129						341
	Amount digested.....		2,366	317	430	1,619	59	11,577
	Per cent digested.....		95	89	94	97	76	
	BASAL RATION AND LADY PEAS.							
	<i>Experiment No. 360, subject K.</i>							
	Basal ration as in experiment No. 357, reduced 25 per cent.....		1,862	267	344	1,251	59	9,500
618	Lady peas.....	700	596	179	12	405	25	2,816
	Total ration.....		2,458	446	356	1,656	84	12,316
629	Feces.....	134	114	53	21	40	20	684
630b	Urine.....	4,855						354
	Amount digested from total ration.....		2,344	393	335	1,616	64	11,278
	Amount digested from lady peas.....		570	155	12	403	19	
	Per cent digested from total ration.....		95	88	94	98	76	92
	Per cent digested from lady peas.....		96	86	100	99	76	
	<i>Experiment No. 363, subject K.</i>							
	Basal ration as in experiment No. 357, reduced 50 per cent.....		1,243	180	229	834	37	6,334
618	Lady peas.....	1,600	1,362	408	28	926	57	6,437
	Total ration.....		2,605	588	257	1,760	94	12,771
343	Feces.....	217	183	84	24	75	34	1,043
634b	Urine.....	5,398						513
	Amount digested from total ration.....		2,422	504	233	1,685	60	11,215
	Amount digested from lady peas.....		1,238	344	18	876	32	
	Per cent digested from total ration.....		93	86	91	96	64	88
	Per cent digested from lady peas.....		91	84	64	95	56	

The results of these experiments were very satisfactory; the different subjects agreed fairly well in thoroughness of digestion of the nutrients of lady peas in the corresponding experiments. The results for B. were practically the same with both the larger and the smaller quantity of legumes, but the other two subjects digested the smaller quantity a trifle more thoroughly than the larger one. The average of the coefficients for the lady peas alone in the six experiments would be, for protein 83 per cent, and carbohydrates 95 per cent.

EXPERIMENTS Nos. 364-367.

On March 5, without intermission from the last of the preceding experiments with lady peas, subjects H. and K. began another series of experiments. For the first four days their diets were the same as those in the basal ration period of the preceding series; and for the next four days this was reduced 40 per cent and supplemented by lady peas in corresponding proportion. The data of these experiments follow:

TABLE 18.—Data of digestion experiments Nos. 364-367.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
	BASAL RATION ALONE.							
	<i>Experiment No. 364, subject H.</i>							
	Basal ration:	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
619	Bread.....	2,800	1,848	306	11	1,531	35	8,288
620	Milk.....	4,000	525	135	188	202	31	3,030
635	Butter.....	200	164	3	161	7	7	1,421
622	Pork.....	120	102	5	97	5	5	888
206	Bananas.....	1,400	310	18	10	282	10	1,251
	Sugar.....	200	200			200		792
	Total ration.....		3,149	467	469	2,215	88	15,646
636	Feces.....	109	93	36	26	32	16	594
638	Urine.....	5,474						635
	Amount digested.....		3,056	431	443	2,183	72	14,417
	Per cent digested.....		97	92	94	98	82	92
	BASAL RATION AND LADY PEAS.							
	<i>Experiment No. 366, subject H.</i>							
	Basal ration as in experiment No. 364, reduced 30 per cent.....		2,204	326	328	1,550	83	10,953
618	Lady peas.....	1,280	1,089	326	22	741	25	5,140
	Total ration.....		3,293	652	350	2,291	108	16,102
630	Feces.....	183	158	69	22	67	25	916
641	Urine.....	5,418						536
	Amount digested from total ration.....		3,135	583	328	2,224	83	14,650
	Amount digested from lady peas.....		1,008	283	20	705	15	
	Per cent digested from total ration.....		95	89	94	97	77	91
	Per cent digested from lady peas.....		93	87	91	95	60	89

TABLE 18.—*Data of digestion experiments Nos. 364–367—Continued.*

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
BASAL RATION ALONE.								
<i>Experiment No. 365, subject K.</i>								
	Basal ration:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
619	Bread.....	1,800	1,188	197	7	984	23	5,315
620	Milk.....	4,000	525	135	188	202	31	3,020
635	Butter.....	200	164	3	161	.....	7	1,421
622	Pork.....	120	102	5	97	.....	5	1,888
206	Bananas.....	1,400	310	18	10	282	10	1,257
	Sugar.....	200	200	.....	.....	200	.....	792
	Total ration.....	.....	2,489	358	463	1,668	76	12,693
637	Feces.....	102	85	34	22	29	17	529
638a	Urine.....	4,318	.....	.....	.....	.....	.....	501
	Amount digested.....	.....	2,404	324	441	1,639	59	11,663
	Per cent digested.....	.....	97	90	95	98	78	92
BASAL RATION AND LADY PEAS.								
<i>Experiment No. 367, subject K.</i>								
	Basal ration as in experiment No. 365, reduced 30 per cent.....	.....	1,742	250	325	1,167	53	8,886
618	Lady peas.....	1,040	885	265	18	602	37	4,184
	Total ration.....	.....	2,627	515	343	1,769	90	13,070
640	Feces.....	150	126	53	20	53	25	734
638a	Urine.....	6,069	.....	.....	.....	.....	.....	577
	Amount digested from total ration.....	.....	2,501	462	323	1,716	65	11,759
	Amount digested from lady peas.....	.....	823	237	14	572	24	.....
	Percent digested from total ration.....	.....	95	90	94	97	72	90
	Percent digested from lady peas.....	.....	93	89	78	95	65	86

Though H. ate a little larger quantity of legumes than K., the results with both subjects agreed very closely. The average coefficients for the lady peas alone in these experiments are for protein 88 per cent and carbohydrates 95 per cent, as compared with 83 and 95 per cent, respectively, in the preceding series.

EXPERIMENTS NOS. 638–643.

This series of experiments was made with the subjects, Fa., Fx., and Ky., who served in a similar series with whippoorwill peas (Nos. 644–649), made later than these but reported on preceding pages (35–37) of the present publication. The basal ration period began December 3, 1903. The diet was alike for all three subjects. In the legume period, beginning December 7, the basal ration for each subject was reduced 40 per cent and supplemented by the same amount of lady peas. The kinds and amounts of food in the basal ration were the same in these experiments as in No. 365 with subject K., but because of differences in composition and heat of combustion, the quantities of nutrients and energy supplied was somewhat larger in the present case. The basal ration was reduced the same proportion in these experiments as in No. 367, but a larger quantity of lady peas was added in the present series. The data of these experiments follow:

TABLE 19.—Data of digestion experiments Nos. 638-643.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
BASAL RATION ALONE.								
<i>Experiment No. 638, subject Fa.</i>								
	Basal ration:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
712	Bread.....	1,800	1,215	172	12	1,031	16	5,404
713	Milk.....	4,000	625	152	278	196	28	4,056
714	Butter.....	200	172	2	170		4	1,573
715	Pork.....	120	106	51	101		4	971
206	Bananas.....	1,400	310	18	10	282	10	1,257
	Sugar.....	200	200			200		792
	Total ration.....		2,629	349	571	1,709	62	14,053
716	Feces.....	69	56	21	16	19	13	363
719	Urine.....	3,465						360
	Amount digested.....		2,573	328	555	1,690	49	13,330
	Per cent digested.....		98	94	97	99	79	95
<i>Experiment No. 639, subject Fz.</i>								
	Total ration as in experiment No. 638.....		2,629	349	571	1,709	62	14,053
717	Feces.....	78	63	24	16	22	15	402
719a	Urine.....	3,310						331
	Amount digested.....		2,566	325	555	1,687	47	13,320
	Per cent digested.....		98	93	97	99	76	95
<i>Experiment No. 640, subject Ky.</i>								
	Total ration as in experiment No. 638.....		2,629	349	571	1,709	62	14,053
718	Feces.....	73	59	19	20	20	14	413
719b	Urine.....	4,525						448
	Amount digested.....		2,570	330	551	1,689	48	13,192
	Per cent digested.....		98	95	96	99	77	94
BASAL RATION AND LADY PEAS.								
<i>Experiment No. 641, subject Fa.</i>								
	Basal ration:							
712	Bread.....	1,080	729	103	7	619	9	3,242
713	Milk.....	2,400	376	91	167	118	17	2,434
714	Butter.....	120	103	1	102		3	944
715	Pork.....	72	64	3	61		3	582
206	Bananas.....	840	186	11	6	169	6	475
	Sugar.....	120	120			120		754
	Total basal ration.....		1,578	209	343	1,026	38	8,431
	Lady peas.....	1,360	1,173	304	24	845	47	5,334
	Total ration.....		2,751	513	367	1,871	85	13,765
720	Feces.....	178	148	62	22	64	30	859
723	Urine.....	3,896						479
	Amount digested from total ration.....		2,603	451	345	1,807	55	12,427
	Amount digested from lady peas.....		1,057	255	12	791	25	
	Per cent digested from total ration.....		95	88	94	97	65	91
	Per cent digested from lady peas.....		89	84	50	94	53	83
<i>Experiment No. 642, subject Fz.</i>								
	Total ration as in experiment No. 641.....		2,751	513	367	1,871	85	13,765
721	Feces.....	215	184	80	17	87	31	1,026
723a	Urine.....	3,956						431
	Amount digested from total ration.....		2,567	433	350	1,784	54	12,308
	Amount digested from lady peas.....		1,024	239	17	768	25	
	Per cent digested from total ration.....		93	84	95	95	66	89
	Per cent digested from lady peas.....		87	79	71	91	53	81

TABLE 19.—*Data of digestion experiments Nos. 638-643—Continued.*

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
722 723b	BASAL RATION AND LADY PEAS—Continued.							
	<i>Experiment No. 643, subject Ky.</i>							
	Total ration as in experiment No. 641.....	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
	Feces.....	197	172	513	367	1,871	85	13,765
	Urine.....	5,292	70	25	77	25	983	487
	Amount digested from total ration.....	2,579	443	342	1,794	60	12,295	
	Amount digested from lady peas.....	1,035	244	13	778	31		
	Percent digested from total ration.....	94	86	93	96	71	89	
	Percent digested from lady peas.....	88	80	54	92	70	82	

These subjects digested the nutrients of the lady peas a little less thoroughly than did H. and K. in the preceding series, averaging 81 per cent for protein and 93 per cent for carbohydrates. The results for Fx. and Ky. agreed quite well, but those for Fa. were larger, especially the coefficient for protein.

EXPERIMENTS NOS. 650-655.

These experiments were made with the same subjects, Fa., Fx., and Ky., and according to the same general plan as the preceding series, but a change was made in the manner of determining the quantities of nutrients and energy in the basal ration, which needs some explanation. In preceding experiments these were ascertained from the weight of each material and its composition as found by separate analyses; but it seemed possible to reduce the number of analyses to one for a given basal ration. The results of previous investigations^a had shown that the analysis of a composite sample made up of aliquot portions of the different food materials in any given ration would show the average composition of the ration as a whole. In the present experiments therefore a composite sample of the basal ration was thus prepared and analyzed in the usual manner, and the results used in computing the quantities of nutrients in the ration. These results apply equally to the full and the reduced ration, of course, because in the latter each item of the original basal ration is reduced in the same proportion, which does not change the percentage composition.

In the first period of the experiments, which began November 29, 1904, each subject ate 2,400 grams of bread, 4,000 grams of milk, 100 grams of butter, 1,400 grams of bananas, and 200 grams of sugar, in the four days. In the second period, beginning December 3, these quan-

^a U. S. Dept. Agr., Office of Experiment Stations Bul. 117, p. 40.

tities were reduced 50 per cent and each subject added 1,700 grams of lady peas for the four days. The data of the experiments follow:

TABLE 20.—Data of digestion experiments Nos. 650–655.

Ref. No.		Total weight.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
BASAL RATION ALONE.								
<i>Experiment No. 650, subject Fa.</i>								
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
750	Basal ration (composite)	8,100	2,774	387	313	2,074	74	13,478
751	Feces	103	87	36	20	31	16	563
754	Urine	3,586						380
	Amount digested		2,687	351	293	2,043	58	12,535
	Per cent digested		97	91	94	99	78	93
<i>Experiment No. 651, subject Fr.</i>								
750	Basal ration (composite)		2,774	387	313	2,074	74	13,478
752	Feces	123	102	41	16	45	21	637
754a	Urine	4,706						329
	Amount digested		2,672	346	297	2,029	53	12,512
	Per cent digested		96	89	95	98	72	93
<i>Experiment No. 652, subject Ky.</i>								
750	Basal ration (composite)		2,774	387	313	2,074	74	13,478
753	Feces	84	68	23	14	31	16	458
754b	Urine	4,794						407
	Amount digested		2,706	364	299	2,043	58	12,613
	Per cent digested		98	94	96	99	78	94
BASAL RATION AND LADY PEAS.								
<i>Experiment No. 653, subject Fa.</i>								
750	Basal ration reduced 50 per cent		1,387	194	156	1,037	37	6,739
749	Lady peas	1,700	1,470	404	30	1,036	60	6,795
	Total ration		2,857	598	186	2,073	97	13,534
755	Feces	214	182	84	28	70	33	1,068
758	Urine	5,062						613
	Amount digested from total ration		2,675	514	158	2,003	64	11,853
	Amount digested from lady peas		1,355	337	11	1,007		
	Per cent digested from total ration		94	86	85	97	66	88
	Per cent digested from lady peas		92	83	37	97		
<i>Experiment No. 654, subject Fr.</i>								
	Total ration as in experiment No. 653		2,857	598	186	2,073	97	13,534
756	Feces	197	169	79	15	75	28	965
758a	Urine	6,247						487
	Amount digested from total ration		2,688	519	171	1,998	69	12,082
	Amount digested from lady peas		1,351	346	23	982		
	Per cent digested from total ration		94	87	92	96	71	89
	Per cent digested from lady peas		92	86	77	95		
<i>Experiment No. 655, subject Ky.</i>								
	Total ration as in experiment No. 653		2,857	598	186	2,073	97	13,534
757	Feces	223	195	85	27	83	28	1,112
	Amount digested from total ration		2,662	513	159	1,990	69	11,784
	Amount digested from lady peas		1,303	331	9	963		
	Per cent digested from total ration		93	86	85	96	71	87
	Per cent digested from lady peas		94	82	30	93		

The results for the different subjects are in fair accord in these experiments, and agree quite well with the best of those obtained in the preceding series. In the average for the three subjects the digestibility of the protein of the lady peas was 84 per cent, and that of carbohydrates 95 per cent.

The coefficients of digestibility of the nutrients of lady peas in the fourteen experiments are here summarized:

TABLE 21.—*Estimated coefficients of digestibility of lady peas.*

Experiment No.	Subject.	Weight of le- gumes eaten.	Total organic matter.	Protein.	Fat.	Carbohy- drates.
		<i>Grams.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
358.....	B.....	700	90	82	.....	97
359.....	H.....	840	89	84	100	93
360.....	K.....	700	96	86	100	93
361.....	B.....	1,600	90	82	34	95
362.....	H.....	2,000	88	80	60	93
363.....	K.....	1,600	91	84	64	95
366.....	H.....	1,280	93	87	91	95
367.....	K.....	1,040	93	89	78	95
641.....	Fa.....	1,360	89	84	50	94
642.....	Fx.....	1,360	87	79	71	91
643.....	Ky.....	1,360	88	80	54	92
653.....	Fa.....	1,700	92	83	37	97
654.....	Fx.....	1,700	92	86	77	95
655.....	Ky.....	1,700	94	82	30	93
Average.....	.....	.....	91	83	65	95

The average of the results for the fourteen experiments with lady peas gives the digestibility of the protein as 83 per cent and of the carbohydrates 95 per cent. The minimum figure for protein is 79 per cent, but in only one case is it below 80 per cent. The maximum is 89 per cent, but the majority of the individual results are not far from the average. The figures for carbohydrates range from 91 to 97 per cent, but most of these also vary little from the average. These results are as a whole very satisfactory.

SUMMARY AND DISCUSSION.

The investigations on the digestibility of legumes here reported include eight experiments with red kidney beans, six with white or navy beans, and thirty-five with different varieties of cowpeas. Of the latter, twelve were with whippoorwill peas, nine with clay peas, and fourteen with lady peas. In each of these experiments the legumes were eaten with a few common food materials. The coefficients of digestibility of the diet as a whole were determined in the usual manner, from the data regarding the ingredients of the food and the feces. The corresponding coefficients for the nutrients of the legumes alone were computed, by making allowance for the digestible nutrients supplied by the materials with which they were eaten. The averages of the results obtained in the experiments with the

different legumes are given in Table 22, which includes both the determined coefficients for the total ration and the computed coefficients for the legumes themselves.

TABLE 22.—*Summary of results of digestion experiments with different legumes.*

Character of diet.	Digestibility of total diet.			Digestibility of legumes alone.	
	Protein.	Fat.	Carbohy- drates.	Protein.	Carbohy- drates.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Basal ration alone.....	91	95	98	.....	.....
Basal ration and kidney beans.....	78	89	95	77	94
Basal ration and white beans.....	81	88	95	78	96
Basal ration and cowpeas, whippoorwill.....	77	91	92	70	87
Basal ration and cowpeas, clay.....	81	93	94	74	88
Basal ration and cowpeas, lady.....	87	91	97	83	95

It is quite evident that as they were eaten in these experiments the legumes were somewhat less thoroughly digested than other common food materials. Thus when the basal ration, which was made up of a few ordinary foods, was eaten alone, 91 per cent of the protein, 95 per cent of the fat, and 98 per cent of the carbohydrates were digested in the average of 23 experiments. These figures, it may be mentioned, are practically identical with those for total food in the average of a large number of American and European experiments with mixed diet.^a But when the legumes were added to the basal ration, the digestibility was lowered, with varying results for the different legumes. It was affected least of all by the addition of the lady cowpeas, and most of all by the whippoorwill cowpeas.

This decrease in the digestibility of the nutrients of the total ration may be due to some direct effect of the presence of legumes on the digestion of the other foods; they may be less thoroughly digested when eaten with legumes than without them. In such cases it might be possible that the coefficients for the nutrients of the total diet would apply alike to all the food materials included. It seems, however, more likely to be that the legumes themselves are, as suggested above, less thoroughly digested than the other foods, which would, of course, give lower percentage results for the total diet with the legumes than for that without them. On the assumption that the thoroughness of digestion of the other food materials would not be materially diminished, the digestibility of the legumes themselves in these experiments would be as shown in the table.

The averages for red kidney beans and white or navy beans are almost exactly the same. If all fourteen experiments with these two kinds of beans were averaged together, the coefficient for protein would be 78 per cent and that for carbohydrates 95 per cent. It has

^a U. S. Dept. Agr., Office of Experiment Stations Bul. 136, p. 112.

been pointed out, however, in the discussion of the results of these experiments in preceding pages, that the average seems to be unduly affected by one or two individual cases that are decidedly out of accord with the others. If these were eliminated, and especially if the deduction were based on the results of those experiments in which the smaller quantities of beans were eaten, the average would be not less than 80 per cent for protein and 97 per cent for carbohydrates.

These figures seem especially favorable, when it is remembered that in all the experiments the legumes supplied the major part of the protein and carbohydrates of a diet that was ample for the subjects under the experimental conditions; and in some of them the proportion was very large indeed. More than that, the results were obtained in experiments in which the beans were eaten by each subject three times a day for four consecutive days. Ordinarily they are not eaten in nearly such large quantities nor for so many meals in succession. There are indications in the results of the experiments, from the increase in digestibility with decrease in proportion of beans to the rest of the diet, that as usually eaten they may be perhaps even more thoroughly digested than here found. But even the average given in Table 22 is equal to that found in corresponding experiments with graham bread.

Among the cowpeas the clay and whippoorwill varieties compare favorably with each other, the digestibility of the protein being a little greater with the former. Even the most favorable average that could be deduced from the results with these two varieties would hardly exceed that for clay peas alone, 74 per cent for protein and 88 per cent for carbohydrates. This is noticeably lower than the average for the beans. The average for the lady peas, however, protein 83 per cent and carbohydrates 95 per cent, compares favorably with that for the beans in respect to carbohydrates and appreciably exceeds it in digestibility of protein. In thoroughness of digestion the lady cowpeas equal entire wheat bread.

In these experiments the legumes were all cooked in the same way, hence the results with the different kinds of legumes are directly comparable. It would be interesting also to have data regarding the digestibility of the same legumes cooked in different ways, to ascertain the effect of cooking. The beans might be eaten with and without the skins, and different methods of preparation might be tried. There is experimental evidence that the bean proteid, when freed as thoroughly as possible from cellulose, is almost completely digested. In experiments with the Japanese preparation *tofu*, which is the proteid of the soy bean precipitated from a solution in a manner not entirely unlike that by which cheese curd is precipitated from milk, 96 per cent of the protein was digested, which equals results obtained with animal foods.

In view of their richness in nutrient constituents, and the extent to which these are digested and absorbed by the body, the legumes deserve a high rank as important food materials. The present bulletin but demonstrates scientifically what has perhaps been long believed instinctively with regard to the value of white and kidney beans, but it also shows that whatever may be claimed for them may be claimed with at least equal fairness for the cowpea also.

The cowpea has a distinctive and pleasing flavor and can be prepared for the table in a great many appetizing ways and compares favorably with other legumes in respect to both nutritive value and digestibility. Its wholesomeness and possible place in the diet is attested by its long and general use in the Southern States. Under usual crop conditions it is reasonable in price and it could undoubtedly be grown in quantities sufficient to meet any demand. The importance of beans, peas, peanuts, lentils, cowpeas, and indeed of legumes as a class is each year becoming more generally recognized as a source of protein in the diet, reasonable in cost as compared with common proteid foods of animal origin, and the use of legumes is increasing.

When all these points are taken into consideration, it seems only fair to conclude that the cowpea deserves to be more generally known and used as a staple food throughout the United States both for its high food value and for the additional variety in the diet which it would help to secure. The importance to southern farmers of widely extending the use of cowpeas as an economical food can hardly be overestimated.

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- Circ. 46. The Functions and Uses of Food. By C. F. Langworthy. Pp. 10.

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- *Food and Diet. By W. O. Atwater. Reprinted from Yearbook of Department of Agriculture for 1894. Pp. 44.
- *Some Results of Dietary Studies in the United States. By A. P. Bryant. Reprinted from Yearbook of Department of Agriculture for 1898. Pp. 14.
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- Nutritive Investigations at the Government Hospital for the Insane, Washington, D. C. By W. O. Atwater. Reprinted from Annual Report of the Office of Experiment Stations for the year ended June 30, 1903. Pp. 14.
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